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1913.

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THE ASSOCIATION was organized in Boston, Mass., on June 21, 1882, with the object of providing its members with means of social intercourse and for the exchange of knowledge pertaining to the construction and management of water works. From an original membership of only TWENTY-SEVEN, its growth has prospered until now it includes the names of over **700** men. Its membership is divided into two principal classes, viz.: MEMBERS and ASSOCIATES. Members are divided into two classes, viz.: RESIDENT and NON-RESIDENT, — the former comprising those residing within the limits of New England, while the latter class includes those residing elsewhere. The INITIATION fee for the former class is FIVE dollars; for the latter, THREE dollars. The annual dues for both classes of Active membership are THREE dollars. Associate membership is open to firms or agents of firms engaged in dealing in water works supplies. The initiation fee for Associate membership is TEN dollars, and the annual dues FIFTEEN dollars. This Association has six regular meetings each year, all of which, except the annual convention in September, are held at Boston.

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ERRATUM.

Insert at page 46, Volume 27, March, 1913, Table 5, Water Consumption of Cities:

Charleston, S. C., population, 58,800, 1912.

New England Water Works Association.

ORGANIZED 1882.

Vol. XXVII. September, 1913. No. 3.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

METHOD OF LOCATING LEAKS IN WATER MAINS.

BY F. J. HOXIE.

[Read September 11, 1913.]

The Inspection Department of the Factory Mutual Insurance Companies has occasionally been requested to assist members in the location of leaks in their underground fire service systems. A job of this sort was assigned to me some years ago, and after exhausting the possibilities of aquaphones and other acoustic devices the following alkaline solution method was developed and successfully applied, locating the leak within six feet in a congested yard where to have dug up any considerable part of the pipe would have seriously interfered with the operation of the mill. Since then several engineers connected with the Inspection Department have successfully used the method in locating leaks in large, complicated yard pipe systems after the resources of the mill have been exhausted without success. In one case one of our engineers assisted the superintendent of a public water works in locating a bad leak in a paved street where it was thought that the whole street would have to be dug up.

Caustic soda was selected in preference to many other possible materials for several reasons. It gives a very sharp indication, is not particularly poisonous, and in the dilute solutions required has no objectionable color, taste, or smell and does no damage to pipes, gates, or fittings. Carbonate of soda, that is, washing soda, or soda ash, will work equally well. The method can be used on public systems by taking the precaution to shut off domestic connection while the measurements are being made, and flushing the pipes afterward as explained.

After locating the leak within reasonable limits by use of section valves and meters its magnitude should be determined by placing a small meter around a closed valve.

No pipe system with much underground pipe can be expected to be absolutely tight. Several careful estimates have been made on well-laid new pipe. About three gallons per day per foot of lead joint is probably a fair average, or approximately 600 gallons per day per 1 000 feet of pipe of sizes commonly found in yard pipe systems, that is, 6 in., 8 in., and 10 in., with an average number of fittings.

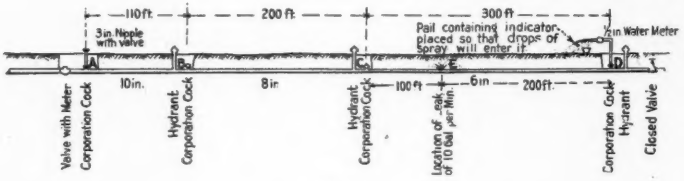


FIG. 1.

Contents of pipe between A and B = 110 x 4.08 = 449 gal.
Contents of pipe between B and C = 200 x 2.62 = 524 gal.
C and E = 100 x 1.47 = 147 gal.
E and D = 200 x 1.47 = 294 gal.
Contents of pipe between C and D = 300 x 1.47 = 441 gal.

Fittings such as check valves, post valves, or drip valves where leaks could occur should be carefully examined. Not infrequently it has been found that a considerable leak was from a poorly packed valve spindle or an imperfectly seated check valve. Sometimes sprinkler drip valves discharge into sewers in such a manner that a small stream of water may trickle through unobserved. Leaks in hydrants are not uncommon. It must be remembered that a half dozen insignificant leaks flowing for twenty-four hours a day may add up to a large amount in the course of a year.

After determining the amount of the leak and its approximate location by use of section valves, the following will be found useful in locating the leak without digging up all the pipe.

The letters refer to Fig. 1, representing a typical example.

Alkali is introduced into the piping as near as possible to the source of supply. This point is marked " A " on the sketch. A $\frac{1}{2}$-in. or $\frac{3}{4}$-in. hole is tapped in the pipe by use of a pipe tapping machine such as is commonly used by the public water works.

To the corporation cock at " A," which is left in the pipe after it is tapped, a 3-in. nipple about 18 in. long is attached with a reducing coupling and nipple at the lower end and a 3-in. valve at the upper end to prevent the water from flowing out. When in place the corporation cock is opened a small amount and the 3-in. nipple allowed to fill with water. Then two or three pounds of solid caustic soda or potash is placed in this 3-in. nipple, the valve closed, and the corporation cock opened so that the caustic solution can diffuse into the pipe. The time that the corporation cock is opened is noted.

If a pump is used for supplying the pressure, great care must be taken that the valve from the primary supply is tight, and that a steady pressure higher than the primary water supply is maintained, otherwise the air in the sprinkler system will cause false indication. Tank or public water of uniform pressure is much easier to manipulate. It is essential, of course, that no water be taken from the system except for measurement while the experiment is going on.

After the alkali has been in the pipe long enough to have arrived at " B," being carried by the leak of 10 gal. per minute, that is, 449 gal. divided by 10 gal. equals 44.9 minutes, a few spoonfuls of water are drawn from the cock at " B " in a pail containing a half teaspoonful of the phenolphthalein indicator. If the red color appears, this shows that all the leak is beyond. If the color should not appear, samples should be tested at minute intervals for fifteen or twenty minutes. If a test is finally obtained, there are probably two or more leaks, part between " A " and " B " and part beyond. At the time calculated for the alkali to appear at " C," tests as above should be repeated at " C." Then at " D," when it is found after waiting ten or fifteen minutes that the alkali has not appeared at " D," a meter should be attached here, read, and the water drawn off until a test is obtained. As soon as red color appears in the pail, the flow should be stopped and the meter read. The difference in the readings represents

the contents of the pipe between " D " and " E," or in the example, 294 gal. This divided by 1.47, the capacity of the pipe in gallons per foot, gives 200 ft., or the distance back along the pipe from " D " to " E."

After completing the test, the hydrant at " D " should be opened and the caustic carefully washed out of the pipes.

If the pipe is level or slants towards " D," a point nearer " D " will probably be indicated, as the caustic solution is heavier than water and tends to flow downward under the water.

With a pipe sloping downward from the source of water to the leak, the indications will be unreliable. With one sloping upward, they will be accurate within the limits of the conditions of the experiment. Very frequently there is not one single leak but several, in which case find first the leak nearest " D." After this is stopped, repeat the experiment, finding that next further away and so on until all are found.

The phenolphthalein solution is formed by dissolving the dry powder, which may be purchased at any chemical supply store, in the proportion of $\frac{1}{8}$ ounce in a pint of wood alcohol.

This method will not be found of much service for single leaks of less than one or two gallons per minute.

Hydrants and calibrated nozzles can be used instead of corporation cocks and meter for preliminary or approximate determinations. The results are not as accurate, however, and leaky hydrant drips may give trouble.

CAPACITY OF PIPES.

Diameter of Pipe. Inches.	CONTENTS OF PIPES PER FOOT OF LENGTH.	
	U. S. Gallons.	Cubic Feet.
4	.65	.087
6	1.47	.196
8	2.62	.349
10	4.08	.545
12	5.87	.785

If water is used from the pipes for drinking, caustic should be used with caution, all drinking connections being shut while the test is being made, and the pipes carefully flushed before they are opened.

Several useful modifications suggested by Mr. C. W. Mowry, M. E., of the Inspection Department, who has had much experience in the use of the method, have been embodied in the above.

DISCUSSION.

MR. ALLEN HAZEN.* *Mr. President,* — The method is certainly an interesting and promising one. It would seem that in following it out the fact that the flow of water is not uniform through the section of the pipe would be a matter that would have to be taken into account. The flow in the center of the pipe is always more rapid than it is along the sides, and there is a great deal of mixing. We know from many experiments that coloring matter or any chemical solution will appear at the end of a pipe before anything like a hundred per cent. of the water in it has been displaced.

MR. R. C. P. COGGESHALL.† *Mr. President,* — The process that Mr. Hoxie suggests might be admirable in our large mill yards where the water in the hydrant and sprinkler system remains dormant, and yet perhaps it might not work in a city supply. How is that, Mr. Hoxie?

MR. HOXIE. It would be absolutely necessary to shut off all flow except that from the leak.

MR. GEORGE A. STACY.‡ I have had a few leaks to locate. I had one on a broken 16-in. main when there was three feet of frost in the ground. It was on a level place and the street was flooded with two to six inches of water by the time we got the water shut off. We tried to locate the break by walking along on top of the trench over the pipe expecting to find a hole, but we did not find anything on the surface. This was quite a mystery until I found a culvert that extended across the street perhaps 40 ft. on one side of the pipe line and 25 or 30 the other, and only a

*Civil Engineer, New York City.
†Superintendent Water Works, New Bedford, Mass.
‡Superintendent Water Works, Marlboro, Mass.

few inches deep, being nearly filled up. The water escaped along the pipe line to the culvert and was forced up through the grating. It seemed a tough problem at first to locate the leak. It was evident that it was either one side or the other of the culvert; how far away I did not know. So I sent for men and drills and we drilled down through the frost a certain distance from the culvert, and when we struck dry ground we tried at the same distance the other side, and we kept dividing up the distance between the last hole and the culvert until we found it, after about one hour and a half's work.

The smaller leaks of course are those that stump us the most to find, and any method that will make that easy for us, so that we can make a better account of the water delivered, will be of great benefit to all. There is no particular investigation that I have made. I feel as though we are full as good as the average, and that the results would not pay for any large expense in looking for leaks. Our ground is about all hard pan, and the few brook crossings are always open for inspection.

MR. HAWLEY.* *Mr. President,* — Mr. Stacy's remarks remind me of an experience I had some years ago where we found that there was a leak in a crossing under a good-sized stream at a time when there was a considerable flow of roily water in that stream. It was necessary to build a cofferdam, but we did not know where the pipe was broken. So we put a corporation cock in the main, and got a bottle of ordinary washing bluing and put that in, and then turned on the water. It didn't take very long to find where the leak was out in the stream through the change of color when the bluing came out of the hole in the pipe.

MR. PATRICK GEAR.† Before the Holyoke water works became a municipal department it was owned by a private corporation, which had cement mains going through some of the streets; but since the municipal department got hold of it they abandoned those cement pipes, but all the connections from them going into the different buildings were left in the ground. One consumer thought he would increase the amount of the water he was getting in his building by hitching on to one of these abandoned services;

*Chief engineer, Pennsylvania Water Company, Wilkinsburg, Pa.
†Superintendent Water Works, Holyoke, Mass.

instead of increasing the supply, the water simply ran back into the old main and showed up on the street. It would come up in John Jones' cellar to-day, and we would dig around there for two or three days, weather down below zero, until we would strike the old pipe, which we would plug up and wait for developments the next day. Now, in plugging up that pipe and trying to find that leak it occurred to me that the engineers of the water departments of the country, while they can overcome big problems, cannot get as near as the engineers in the telephone system.

Last year I broke a telephone wire, and one of the repair gang went up the pole and telephoned to Springfield, twelve miles away. They told him he was still half a mile from the trouble, and he went along about that distance and found it. To be exact, it was just 2,800 ft. If when we have a break in a pipe and we go into the house and hear the noise in the pipe, the water-works engineer could find some way that would tell us how far away the break was, we would be all right.

But coming back to the cement pipe that we had the trouble with; we were digging down there for a long time and Mr. Tighe suggested that we start at both ends of it. So we plugged the pipe and waited for developments. It would come up in John Smith's cellar the next day, and we would go and plug that up; and we were at it until we had gone through the street and all the cross streets connected with it. Finally we located the connection in an old printing establishment where they wanted water for printing presses.

We had a leak show up at the toe of an earthen dam that we built up there ten or fifteen years ago. There was some question whether it was in the pipe or in the dam. When we were building this dam we laid some 24-in. pipe through it, and we didn't want to put concrete all round the pipe, — that was too much expense,— so we built a couple of piers under our pipe; and in the course of a few years the pipe cracked where those piers were. There was a nice leak there that we discovered by shutting the gates on both sides of it. We dug down 30 or 40 feet and put concrete under the pipes, and they are all right now.

We have some canals in Holyoke; three or four of them run

through the city, and we have had to run pipes over them and under them, and duck them every way, and we have leaks in those canals once in a while. When you get three or four feet of ice in the canal, and your pressure gage in the office shows that you are losing water, you have to take the gang out and have them go to all those gates as they cross the canal and locate the trouble. Where it isn't deep you have to have a man see if there is any bubbling in the water; and he will generally find it in the last one he tries.

MR. HOXIE. Mr. Hazen's remarks undoubtedly apply to pipes with considerable velocity of flow. With leaks of such magnitude a method such as that described would not often be required, as shown by the experiences just given by several gentlemen. The most troublesome leaks are those from 5 to 50 gallons per minute. This method has been successfully used by our engineers in locating a dozen or more leaks within the last few years, showing that irregularities and velocity are of little importance within the range of its greatest usefulness.

THE CITY TUNNEL AND CONDUITS OF THE CATSKILL AQUEDUCT.

BY WALTER E. SPEAR, DEPARTMENT ENGINEER, BOARD OF WATER SUPPLY, CITY OF NEW YORK.

[*Read September 11, 1913.*]

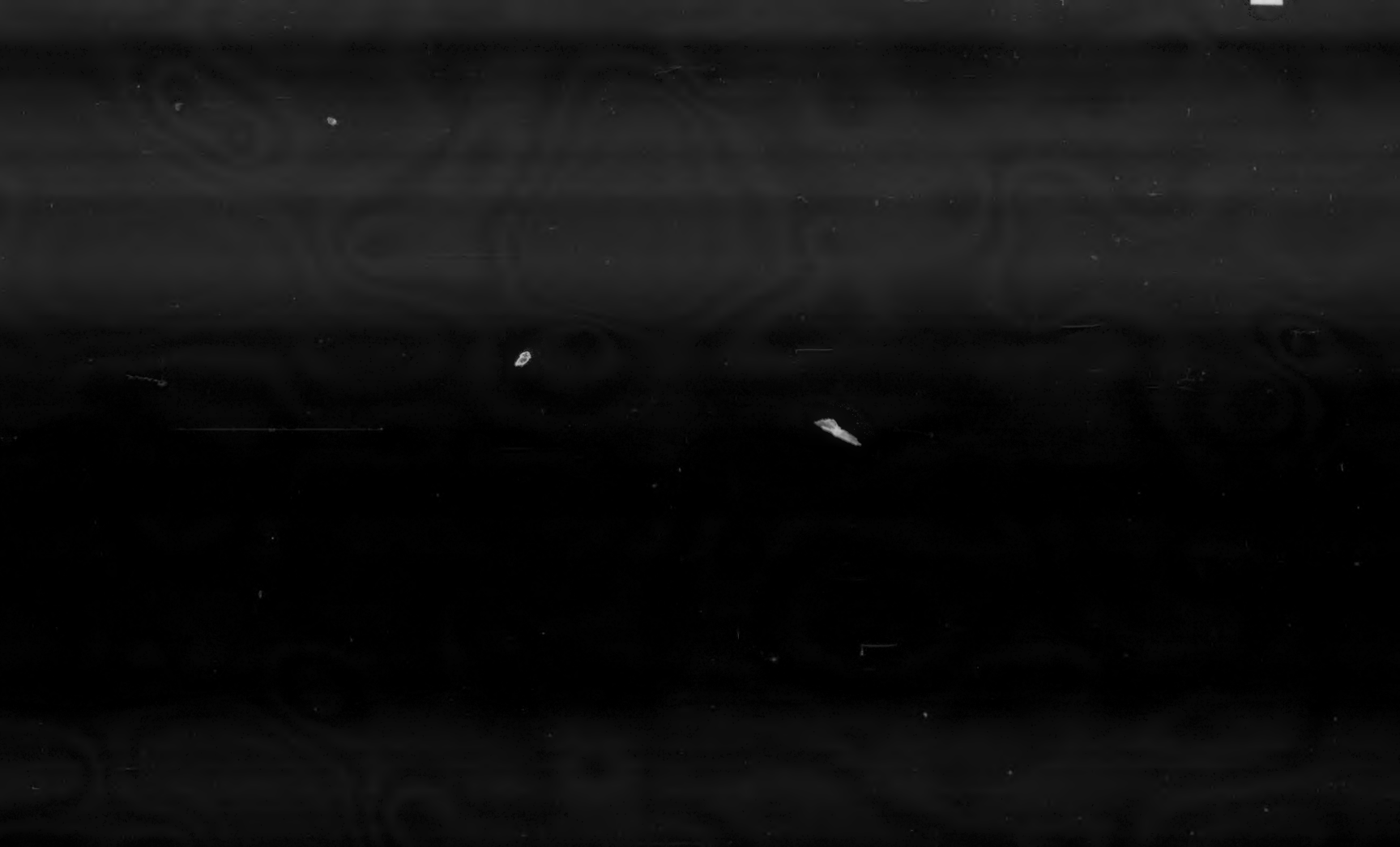
By reason of the peculiar topography of New York City and the extent to which the subsurface space in the older business and residential streets of Manhattan and Brooklyn boroughs is already occupied, the delivery of the new Catskill supply to the great centers of population in these boroughs, as well as to the widely separated suburban sections of the city, presented a most unusual problem. Its solution made by the Board of Water Supply in the large pressure tunnel nearly 18 miles in length, which is being constructed in the bed rock through the heart of the city, is unique in waterworks construction.

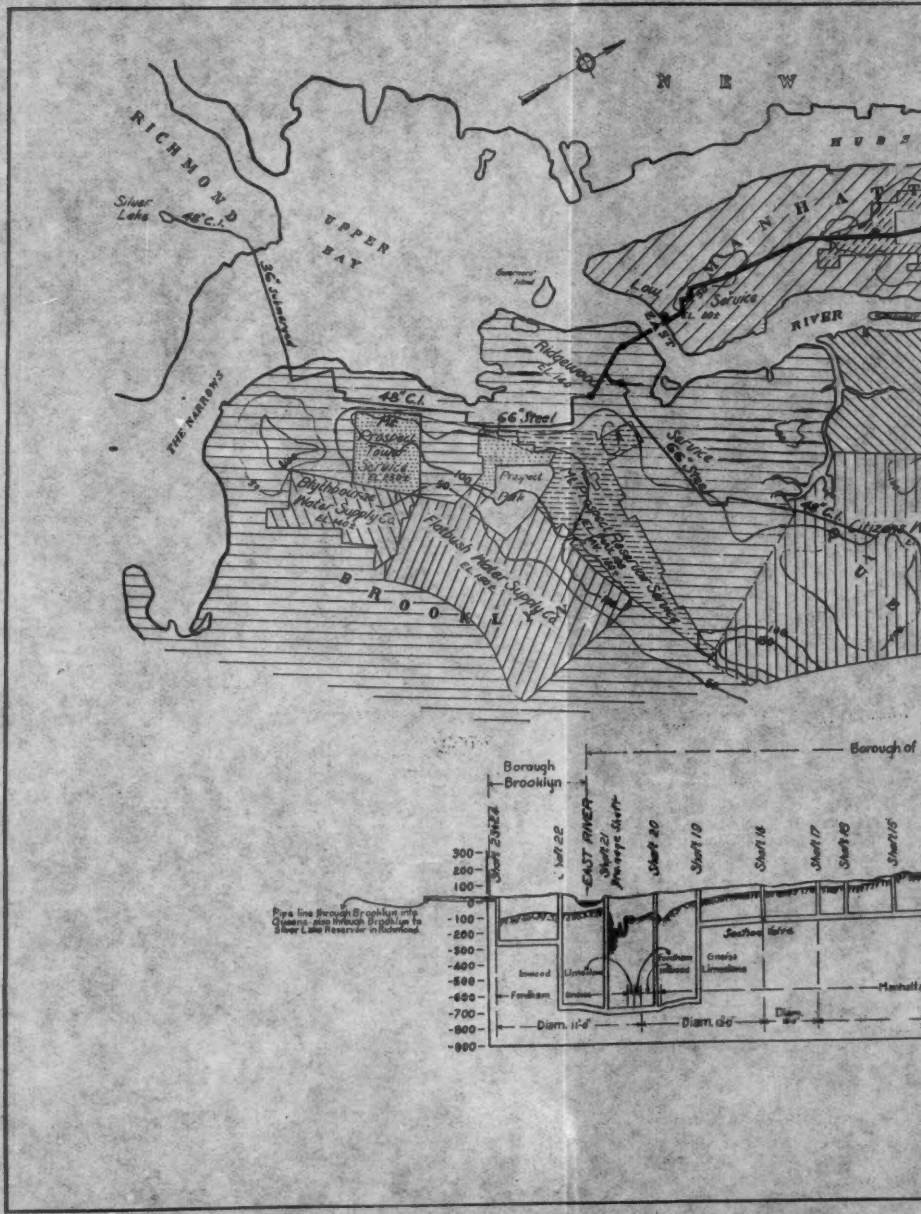
As this problem of distributing the Catskill supply was approached, it was at once seen that the task of finding sufficient room in the older streets of the city for the number of 48-in. and 66-in. mains necessary to carry 500 million gallons of water per day with a reasonable loss of head was quite impossible, and larger pipes could not be considered. The streets in which many of these trunk mains would necessarily have to be laid were already occupied by sewers, pipes, and ducts, including the large trunk mains of the present water-supply system, which in Manhattan Borough must to a large extent be reserved for the delivery of the Croton supply to the lower portions of the borough; the existing subways also interposed an effective barrier to the laying of large water mains, and the new subways were laid out in many of the streets in which it would be necessary to place the large conduits for the transportation of the Catskill supply. Aside from these physical difficulties and the great inconvenience and loss which the public would suffer from constructing these mains in the streets, the expense of delivering the Catskill supply in steel or cast-iron mains was found to be excessive, and another solution had to be found.

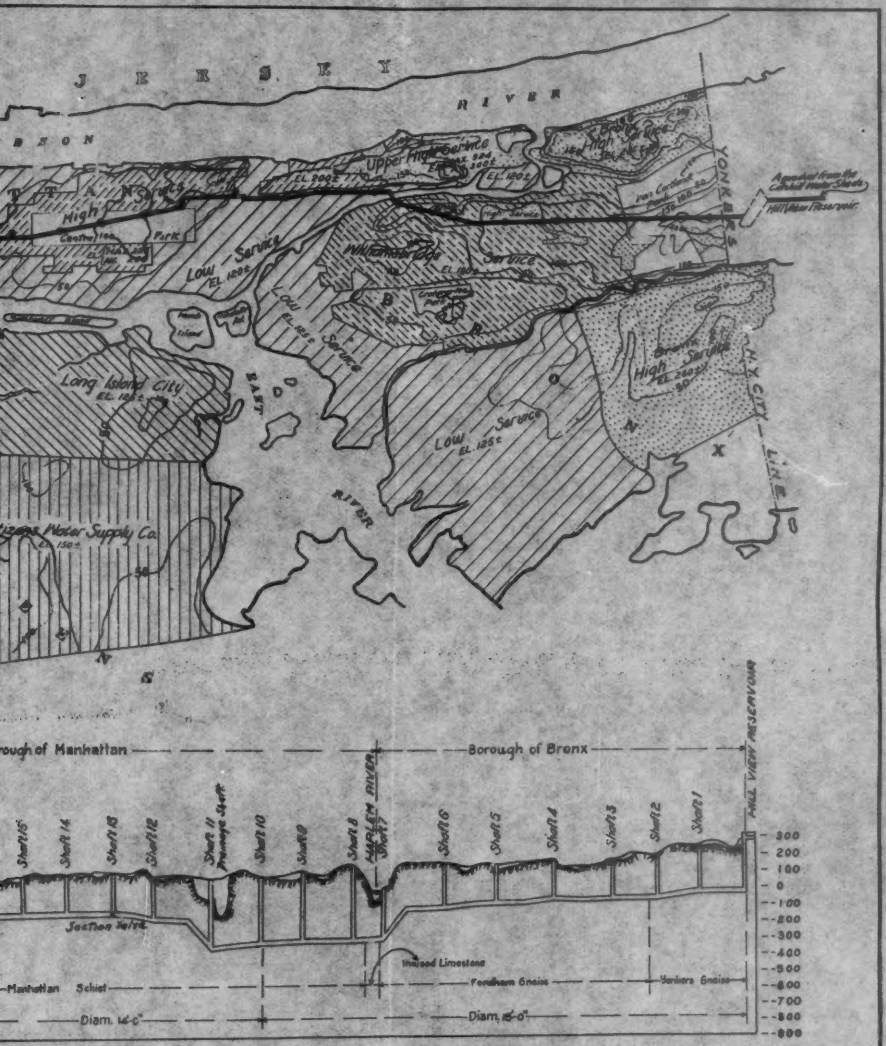
The brick-lined pressure tunnel, which was built twenty-five years ago as a part of the New Croton Aqueduct from Van Cortlandt Park to Amsterdam Avenue and 135th Street in Manhattan Borough, had already demonstrated the possibilities of deep rock tunnels for the transportation of water in the city, and the successful concrete-lined pressure tunnels more recently constructed outside of the city as a part of the Catskill Aqueduct, pointed the way to a solution of this problem of delivering the Catskill supply to New York City. It was readily demonstrated that such a tunnel, with frequent outlets, having a capacity equivalent to the full yield of the Catskill sources, could be carried deep in the bed rock under the city from the new Hill View reservoir in Yonkers, through the boroughs of The Bronx and Manhattan to the borough of Brooklyn, at half the expense of laying an equivalent number of cast-iron or steel mains, and that this tunnel was in every way superior to a system of pipes in the streets.

DESCRIPTION OF TUNNEL.

The general alignment and depth of the city tunnel, as the tunnel portion of the Catskill Aqueduct in the city is termed, is seen in Plate XVII. It may be noted that the line is located on the highest ground in the boroughs of The Bronx and Manhattan and crosses the East River at the southerly end of Manhattan Island to the downtown business section of Brooklyn, passing through many of the high-service districts and reaching the centers of population and the great business districts where the greatest consumption exists and the highest pressures must be maintained. The tunnel has a length within the city of 17.7 miles, and is entirely under public waterways, parks, and streets except for 1 027 ft., or 1.1 per cent. of the total length, in which easements over private land had to be secured. All but four of the shafts are likewise located in parks or streets, so that but little real estate had to be acquired by the city for the project. The depth of the tunnel for fully half its length is seen in the profile to be about 200 ft. below the surface, but in order to keep the tunnel in bed rock south of the Harlem River, on the lower east side of Manhattan Borough and in Brooklyn, the grade was fixed at greater depths, as will be later explained. Unlike the pressure tunnels previously




N E W
RICHMOND
Silver Lake
48"C.I.
UPPER BAY
36" Submerged
THE NARROWS
Governors Island
Low Service
RIVER
Ridgewood
66" Steel
48"C.I.
66" Steel
Service
Air Cooling Tower Service
Prospect
Bklyn Water Supply Co.
Flatbush Water Supply Co.
Borough Brooklyn
Borough of
EAST RIVER
Shaft 23
Shaft 22
Shaft 21
Shaft 20
Shaft 19
Shaft 18
Shaft 17
Shaft 16
Shaft 15
Pipe line through Brooklyn into Queens - also through Brooklyn to Silver Lake Reservoir in Richmond
300
200
100
0
-100
-200
-300
-400
-500
-600
-700
-800
-900
Section Valve
Limestone
Manhatt
Diam. 11'-6"
Diam. 12'-6"



City of New York
BOARD OF WATER SUPPLY
CATSKILL AQUEDUCT
CITY TUNNEL AND CONDUITS
PLAN AND PROFILE

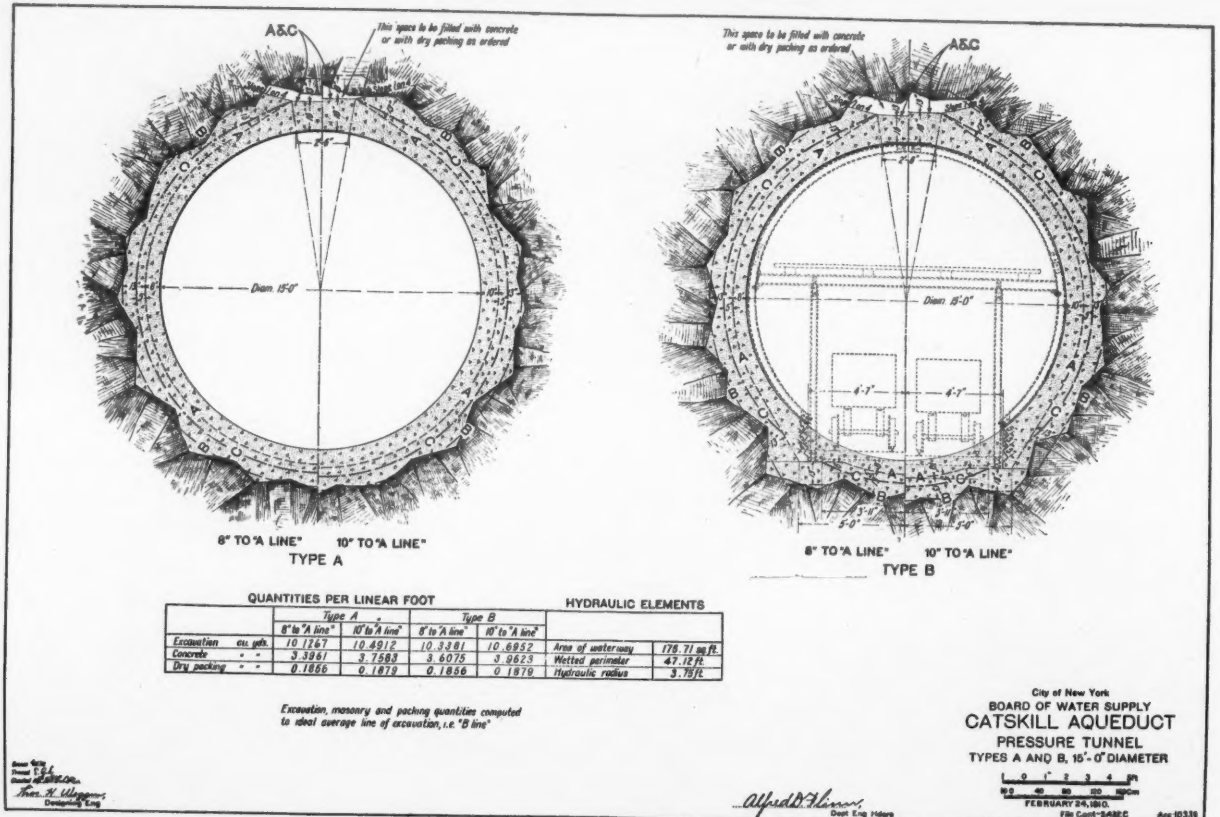
AUGUST 21, 1913.

File Acc. C 5406

constructed, the city tunnel is to perform the functions of a trunk distribution main. It is not to be simply an aqueduct delivering its entire flow to some objective point, since this tunnel is to have waterway shafts at intervals of about three fourths of a mile, through which water in large volumes may be discharged directly into the distribution mains.

Because of the draft from the tunnel through these shafts it is not necessary to provide for the entire tunnel a capacity equivalent to the full flow of the Catskill Aqueduct, and a successive reduction in size is accordingly made at several points in Manhattan Borough. The tunnel has a finished diameter of 15 ft. for the first 7.7 miles from Hill View reservoir as far as Shaft 10, in St. Nicholas Park, at 135th Street; 14 ft. for the next 5.0 miles to Shaft 17, in Bryant Park, at 41st Street; 13 ft. as far as Shaft 18, at Broadway and 24th Street, a further distance of 0.9 mile; and 12 ft. for 2.0 miles further to a point near Orchard and Hester streets, 1 500 ft. south of Shaft 20. Beyond this point the remainder of the main tunnel leading to the terminal shaft, No. 23, at Flatbush Avenue and Schermerhorn Street, Brooklyn, and the branch to Shaft 24, in Fort Greene Park, having a total length of 2.5 miles, has a diameter of only 11 ft. A section of the 15-ft. tunnel is seen in Fig. 1. This is typical of the other tunnel sections and shows the amount of excavation and the thickness of the concrete masonry lining. A minimum thickness of concrete of 10 in., within which no rock is allowed, has been provided, but the effective thickness inside of any considerable area of rock is 15 in. As a result of the generally wide breakage in the city tunnel, however, the actual thickness of the lining will average fully 23 in.; that is, out to the "B" line, shown on the cross-section, to which payment for excavation and concrete is made. In sections where much seepage through the rock occurs the tunnel is excavated even wider, and a thicker lining provided to resist grouting pressures and insure water-tight work.

Of the 24 shafts through which the tunnel is being constructed, 22 of them are to be finished as waterways; No. 1, the first within the city limits, is to be filled upon the completion of the tunnel; and No. 11 is to be a drainage shaft through which the northerly half of the tunnel may be unwatered. Provisions for draining the



QUANTITIES PER LINEAR FOOT

	Type A		Type B	
	8" to "A line"	10" to "A line"	8" to "A line"	10" to "A line"
Excavation cu. yds.	10.1267	10.4912	10.3381	10.6952
Concrete " "	3.3961	3.7583	3.6075	3.9623
Dry packing " "	0.1856	0.1879	0.1856	0.1879

HYDRAULIC ELEMENTS

Area of waterway	176.71 sq. ft.
Wetted perimeter	47.12 ft.
Hydraulic radius	3.75 ft.

Excavation, masonry and packing quantities computed to ideal average line of excavation, i.e. "B line"

Alfred D. Flinn, Dept. Eng. Hdqrs.

City of New York
BOARD OF WATER SUPPLY
CATSKILL AQUEDUCT
PRESSURE TUNNEL
TYPES A AND B, 15'-0" DIAMETER

FEBRUARY 24, 1910.
File Cont-3482C Acc 10339

FIG. 1.

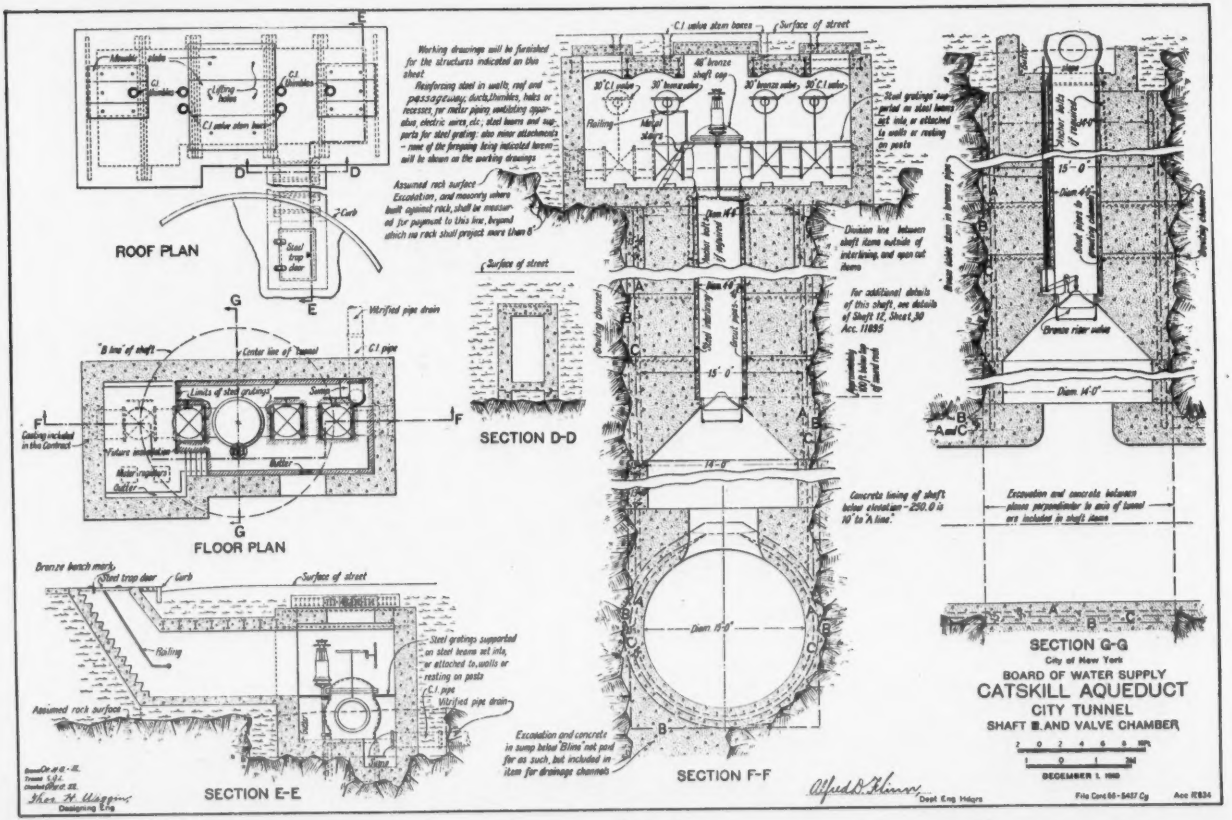

ROOF PLAN
FLOOR PLAN
SECTION D-D
SECTION E-E
SECTION F-F
SECTION G-G
City of New York
BOARD OF WATER SUPPLY
CATSKILL AQUEDUCT
CITY TUNNEL
SHAFT B AND VALVE CHAMBER
DECEMBER 1, 1910
Working drawings will be furnished for the structures indicated on this sheet
Reinforcing steel in walls, roof and passageways; ducts, thimbles, holes or recesses for meter piping sweetening apparatus, electric wires, etc.; steel beams and supports for steel grating; also minor attachments — none of the foregoing being indicated hereon will be shown on the working drawings
Assumed rock surface
Excavation, and masonry where built against rock, shall be measured for payment to this line, beyond which no rock shall project more than 6"
Steel gratings supported on steel beams set into, or attached to, walls or resting on posts
Division line between shaft items outside of interlining, and open cut items
For additional details of this shaft, see details of Shaft 12, Sheet 30 Acc. 11895
Concrete lining of shaft below steel plan — 250.0 is 10' to "A line."
Excavation and concrete between planes perpendicular to axis of tunnel are included in shaft items
Excavation and concrete in sump below "B line" not paid for as such, but included in item for drainage channels
Vitrified pipe drain
C.I. pipe
Steel trap door
Curb
Railing
Surface of street
Bronze bench mark
Assumed rock surface
Steel grating supported on steel beams set into, or attached to, walls or resting on posts
Limits of steel gratings
Sump
Gutter
Future installation
Casting included in this Contract
"B line" of shaft
Center line of tunnel
Diam 14'-0"
Diam 15'-0"
Diam 13'-9"
14'-8"
15'-0"
Bronze riser valves
Bronze plate
Anchor bolts if required
Steel gratings supported on steel beams set into, or attached to walls or resting on posts
30" C.I. valve
30" bronze valve
48" bronze shaft cap
Nickel steel
Railing
Diam 4'-6"
Steel lining
Anchor bolts if required
Bronze plate
Anchor plates in bronze plate
Steel plate to which valves are attached
Bronze riser valves
Diam 14'-0"
Manhole
Slate
C.I. thimbles
Lifting holes
C.I. valve stem boxes
Curb
Steel trap door
Surface of street
Alfred D. Flinn
Dept. Eng. Inspr.
Thos. H. Higgins
Designing Eng.
File Cons 66-5437 Cg
Acc 12834

FIG. 2.

southerly half of the tunnel are being made at Shaft 21, but this shaft is also to have a waterway.

One of the most interesting features of the city tunnel is the design of these waterway shafts, a typical section of which is shown in Fig. 2. The diameter inside of the outer lining of concrete masonry is 14 ft., and the minimum thickness of lining to the "A" line from 8 to 10 in. The shafts with the largest waterways, Nos. 3, 23, and 24, have diameters about 2 ft. greater than here shown, and the drainage shafts, Nos. 11 and 21, are excavated equally large to provide for a double lining separated by tiling to carry off seepage. From a point 100 ft. below the rock surface, the section of the shaft is to be constructed to a diameter of only 4 ft. within a concrete-lined steel riser pipe, solidly concreted into the shaft. This riser is to be capped at the top, within the large masonry valve chamber just below the surface of the ground, by a bronze tee having two 30-in. outlets, to each of which are to be attached in tandem two gate valves, one a bronze-mounted service valve and another of solid bronze placed next to the tee. The latter valve, which may be closed in the valve chamber or from the surface above the chamber, is intended to be used when the service valve is out of order. At most of the shafts, on by-passes about the service valves, regulating valves are to be installed by which the pressure on the distribution side may be controlled to meet the service requirements.

In addition to these valves at the top of the riser pipe, an emergency valve of the needle valve pattern is to be provided in the shaft of the foot of the riser, which is designed to automatically close when the discharge through the riser exceeds a certain velocity, and which can also be closed by hand either from the chamber or from a control on the surface at some distance from the shaft. All but three shafts are of the circular type just described, though some have two risers of the same size instead of one. Of these exceptions, Shaft 21, the drainage shaft, is approximately egg-shaped, to include both the 14-ft. drainage well and the standard 48-in. waterway; and Shafts 13 and 18, which are section valve shafts, are roughly rectangular to provide space for a well over the section valve in the tunnel and for two 48-in. waterways, taking out of the tunnel on either side of the section valve. Note in

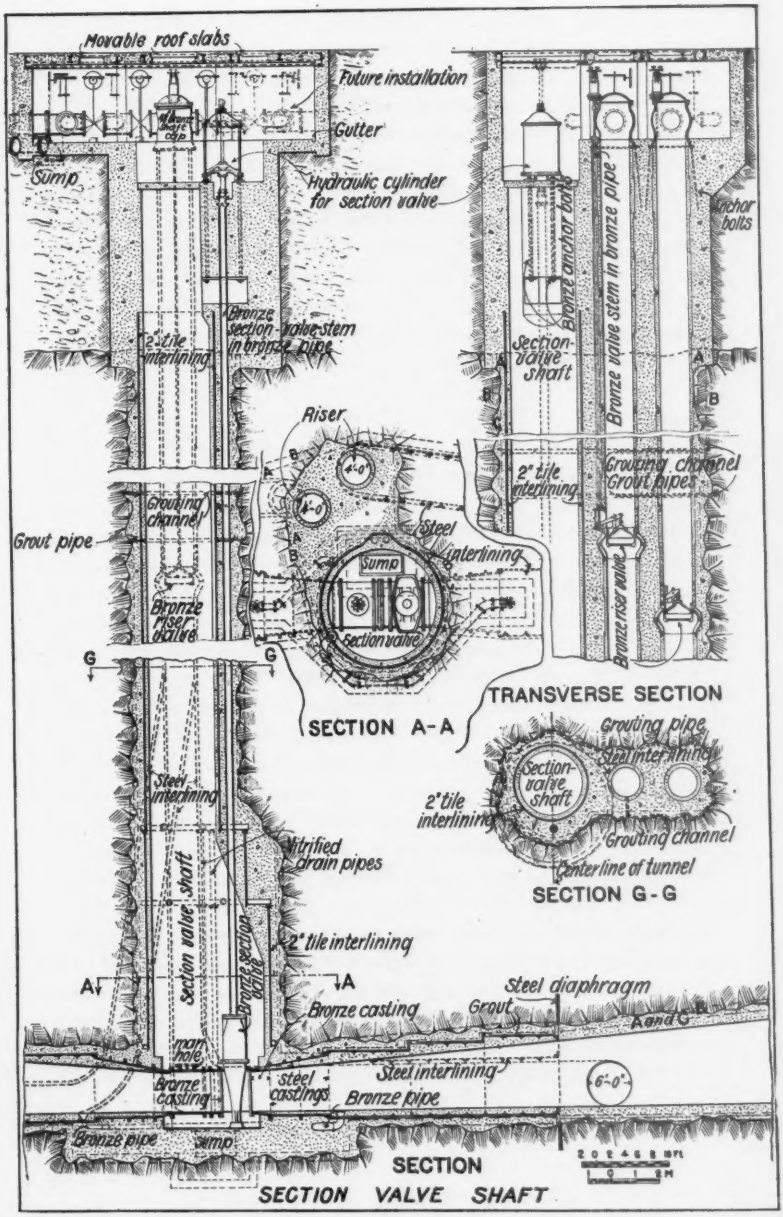

Movable roof slabs
Future installation
Gutter
Sump
Hydraulic cylinder for section valve
Bronze section-valve stem in bronze pipe
2" tile interlining
Bronze anchor bolts
Bronze valve stem in bronze pipe
Anchor bolts
Section-valve shaft
Riser
Grouting channel
Grout pipes
Grout pipe
Steel interlining
Sump
Bronze riser valve
Section valve
TRANSVERSE SECTION
SECTION A-A
Grouting pipe
Steel interlining
2" tile interlining
Vitrified drain pipes
Steel diaphragm
Grout
Bronze casting
Steel castings
Bronze pipe
Steel interlining
SECTION G-G
SECTION
SECTION VALVE SHAFT

FIG. 3.

Fig. 3, which shows the general design of these shafts, that the section valve is to have a clear waterway of 66 in. and that the tunnel is to be contracted on either side to this diameter in long tapered transition sections to minimize the loss of head. The purpose of these section valves is primarily to permit of cutting off and draining the southerly portion of the tunnel south of Shaft 13 or 18 while still operating the northerly portion.

The amount of water delivered to the city is to be measured by a Venturi meter placed in the main tunnel just north of Shaft 2, the first waterway shaft below Hill View reservoir. The throat of the meter is designed to have a diameter of 8.67 ft. with appropriate sections on either side, through which the transition is made from the 15-ft. tunnel section.

PRELIMINARY INVESTIGATIONS.

No project was ever more thoroughly investigated than the city tunnel, and the rapid progress which has been made in driving the tunnel and the freedom from serious difficulties which has been experienced have more than justified the comparatively small expense of the preliminary work; altogether 201 borings, aggregating 46 343 ft., were made and over two years spent on surveys and studies before contracts were finally prepared. In the early stages of the investigations the Board of Water Supply was fortunate in having the services of Dr. Charles P. Berkey, consulting geologist, to whom great credit is due for the success of the undertaking. Dr. Berkey was able, from his intimate knowledge of the geology of the city, to point out the hidden fault lines and foldings in the rock formation where difficulties might be expected in driving a tunnel, so that attention could be given at once to these localities. No lesson was more thoroughly impressed upon the engineers connected with this work than that demonstrated on the city tunnel, as well as on other parts of the Catskill Aqueduct, that economy of time and money was to be secured in locating large engineering structures by securing the best geological advice.

Conditions in New York City are, on the whole, very favorable for a pressure tunnel of the type which is being constructed; but few other large cities are similarly built on the solid rock. From the Yonkers line to the lower portion of Manhattan Island

the rock, comprising the Yonkers and Fordham gneiss and the Manhattan schist formations, is, generally, at or near the surface, and it was possible to place over half the length of the tunnel at a depth of not much over 200 ft. below the surface, a minimum depth of 150 ft. of sound rock over the tunnel being considered essential to obtain good tunneling ground and to insure a maximum of water-tightness in the finished structure, which is to carry an unbalanced head of about 300 ft. In the section of the tunnel, however, from the Harlem River to Morningside Park, it was necessary to go somewhat deeper than 200 ft. in order to secure the requisite depth of rock cover over the tunnel.

The Inwood limestone underlying the Harlem River had been disintegrated and eroded to some depth, and a deep gorge in the bed rock was believed by the geologist to have been plowed by the ice in a weak zone in the Manhattan schist near 125th Street. In this section the tunnel was, therefore, located at a depth of 300 ft. below sea level and in some points over 400 ft. below the surface. A still greater depth was found necessary on the lower east side of Manhattan in passing through Inwood limestone and Fordham gneiss. Much disintegration in these rocks was found by the borings in Hester Street near Seward Park at a depth of 400 ft. to 500 ft., and some depth of decay was developed also on Delancey and Clinton streets, so that it was not considered safe to place the tunnel between the Bowery and the East River at a depth of less than 700 ft. below sea level. In Brooklyn, the grano-diorite intrusion in the Fordham series, which had largely displaced the sedimentary rock, was found to fall off rapidly toward the south and east beyond the corner of Fulton and Flatbush avenues, and the increasing depth of drift over the rock fixed the southerly limits of the tunnel at Shaft 23. A depth of 300 ft. to the tunnel grade was required in Brooklyn to secure the necessary cover of rock at that point.

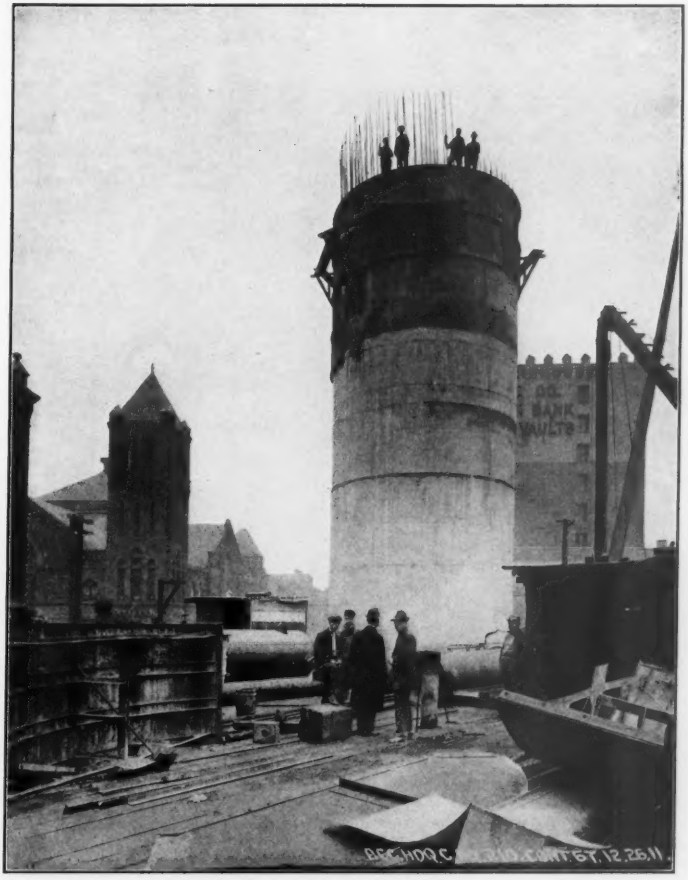
The borings for the city tunnel were entirely done by contract, and, on the whole, extremely satisfactory work was secured. Both shot and diamond drills were used, though the deeper work was done by the latter. The large shot drill cores, $1\frac{3}{4}$ to 3 in. diameter, were most satisfactory, but difficulty was met in securing a hole sufficiently straight to go much deeper than 200 ft. without

frequent breaking of the drill rods and consequent interruption in the work. The cores from the diamond drill machines were, on the other hand, rather too small, being only $\frac{13}{16}$ to $1\frac{3}{4}$ in. in diameter, and the results in a few instances were perhaps misleading. At the bottom of the deeper holes on the lower east side, where most of the boring with diamond drills was done, and where depths of 750 ft. were secured, sometimes only a small percentage of the rock penetrated was cored. Besides the handicap of the small size of the core barrel, the failure to secure a greater amount of core in these deep holes was due in some measure to the structure of the rock, which was not strongly cemented together and was tilted up at a high angle, and occasionally to the drill rods supporting the core barrel becoming slightly bent.

CONSTRUCTION.

Contracts for the city tunnel were let in four sections and work begun in June, 1911, and it is expected that the entire work will be completed on schedule time ready for the delivery of water into the city's mains by the latter part of 1915. At the present time, after twenty-six months' work, the city tunnel is 65 per cent. completed; 95 per cent. has been excavated and 20 per cent. lined. One of the four sections of the tunnel is now so far advanced that it will be substantially completed inside of six months.

No great delay was experienced in starting the excavation of the shafts in rock except on the southerly section, where the rock surface is too far below the ground surface to permit of excavating through the drift by other than pneumatic methods. Reinforced concrete caissons 15.3 to 18.0 ft. in interior diameter, with walls 2 to 3 ft. in thickness, were sunk to rock and tightly sealed. Some idea of these caissons may be gained from Plate XVIII. The photograph was taken of the deepest caisson of Shaft 23 when there was about 40 ft. of the caisson below the street surface and some 80 ft. above. Fig. 1 of Plate XIX is a photograph of the caisson at Shaft 24 when being concreted; Fig. 2 shows the bottom of the caisson and the rods to be bent out for the deck. Each of the vertical reinforcing rods shown in this photograph has a turnbuckle at the bottom of the caisson with which it is connected through the sloping face of the V-shaped cutting edge to other



CAISSON AT SHAFT 23.

FIG. 1.
REINFORCEMENT OF CAISSON AT SHAFT 24.

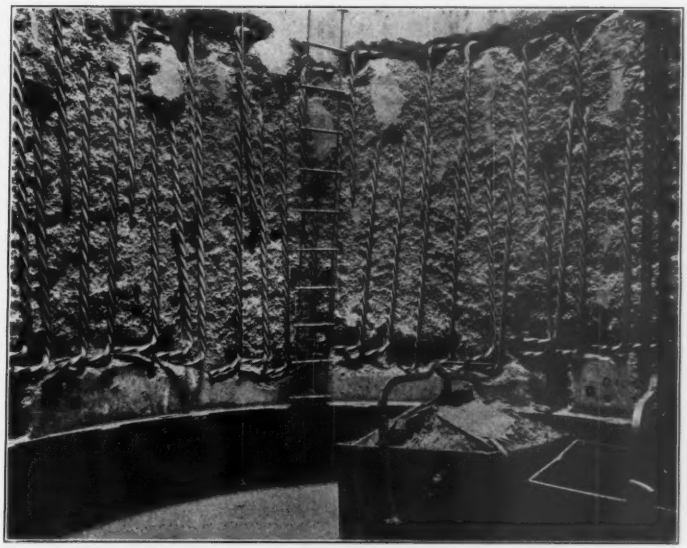


FIG. 2.
BOTTOM OF CAISSON.

rods anchored in the concrete of the shaft, well below the surface of the rock. No shaft caisson was sunk at the drainage shaft, No. 21, but four shallow wall caissons enclosing the shaft were put down for the support of the superstructures to be erected over the drainage equipment and the space within them excavated to rock.

From two to three months were consumed in sinking the shaft caissons and in sealing them, from the time the steel shoes were set up in the bottom of the chamber excavation, and maximum air pressures from 17 to 46 lb. per sq. in. were used. So carefully was the work done that no appreciable settlement that could be attributed to the caisson work was observed in the vicinity of the shafts.

The depths of the rock shafts of the city tunnel range from 156 to 714 ft., and, with the exception of the timbered section valve shafts, the outer concrete lining was generally placed in stretches of 100 ft. as the shafts were excavated. From 2.5 to 7.7 months were taken in sinking and lining the shallower shafts in the neighborhood of 200 ft. in depth, and from 6.5 to 12.5 months for the deeper ones, from 250 to 450 ft. in depth. Shaft 21, which has a larger cross-section than the other concrete-lined shafts, and a total depth in rock of 714 ft. to the bottom of the drainage sump, took 14.5 months. The best month's record on all contracts in sinking and lining was 112 ft. at Shaft 20, the average about 50 ft. ranging at the several shafts from 25 to 82 ft.

The first tunnel headings were turned at Shaft 14 in Central Park in December, 1911, and the last at Shaft 21 in February, 1913. At present, 95 per cent. of the entire tunnel has been excavated, leaving less than 5 000 ft. to be driven. The top heading and bench method common in this country has been generally used in excavating the tunnel, and some idea of this work may be had from the photographs in Plate XX. Fig. 1 shows the heading with muck being removed over the bench; Fig. 2 the completely excavated section. Pneumatic drills have been generally employed both in shafts and tunnels, although some extensive trials of electric drills were made by one of the contractors. Except for the northerly section of the tunnel, which is largely in undeveloped sections of the city where a central steam-driven compressor plant could be erected, each shaft, or, in one case in

Central Park, a group of three shafts, was equipped with a compressor plant of 1 to 3 electrically-driven units. All shaft hoists, ventilating fans, and most of the pumps in the tunnel, are also electrically driven as required by one of the clauses of the tunnel contracts, which specifies that so far as practicable, all equipment be driven by electricity to minimize the noise and dust incidental to the operation of steam plants. Among other measures adopted for the safety of the public as well as the workmen in the tunnel was the storage of the explosives at each shaft in a large underground magazine excavated in the rock at tunnel grade and connected with the tunnel by a tortuous drift, driven laterally from a point 100 ft. from the shaft. A heavy steel and timber door, hung in a concrete bulkhead at the entrance to this drift, was designed to protect the workmen from the gases of combustion should an explosion occur in the magazine.

No records in tunnel driving or in shaft sinking have been broken on the city tunnel. The routine and methods usually employed in carrying on mining operations in the country have had, of course, to be materially modified in doing such work in the heart of a large city. The best progress thus far made in excavating the tunnel has been that in the Inwood limestone in the south heading of Shaft 20, where 354 ft. of completely driven tunnel of 11-ft. finished diameter were excavated in one month. The average progress on the several sections has been from 150 ft. to 250 ft. per month, according to the difficulties encountered and the speed which the contractors considered it necessary to push this part of their work.

The lining of the tunnel is well under way on only one section, where six sets of sidewall and arch forms are being concreted from two central mixing plants. On this section nearly 17 000 ft. of lining, or about three quarters of the contract, has been placed. A beginning has been made on the other three sections of the tunnel, but thus far only about 2 000 ft. of lining has been put in.

The methods of concreting in the city tunnel differ little from those which have been developed on other tunnels of the Catskill Aqueduct, though a somewhat richer concrete, mixed in the proportions of 1 of cement to 1½ of sand or screenings and 3 of stone or gravel, is being used in the city. First the concrete of the

FIG. 1.
REMOVING MUCK FROM THE HEADING.

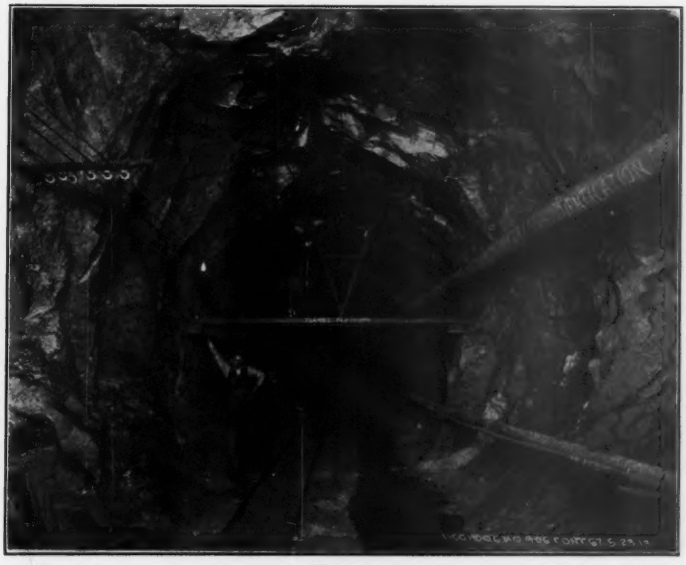


FIG. 2.
COMPLETELY EXCAVATED TUNNEL.
SHOWING TRACK, AIR PIPES AND ENGINEERS' INSTRUMENT PLATFORM.

invert for a width of 5 to 6 ft. is laid against radial form boards. This part of the concreting goes rapidly, since from 150 to 200 ft. may be readily placed in an eight-hour shift. It is customary to lay all the invert in any section before starting the next operation. After the invert is finished the sidewalls are concreted to the springing line, and finally the arch is placed. The last two operations have come to be done simultaneously, the sidewall being concreted with an adjacent section of arch.

This plan permits the mixing plant to be run at full capacity during the slowest and most difficult part of the concreting, the keying of the arch, the surplus concrete going to the sidewall form. Most of the concrete lining in the city tunnel, thus far put in, has been placed in sidewall and arch forms 60 ft. in length, all in tunnels of 13 and 14 ft. in finished diameter, but forms 80 ft. long are being successfully used in the 12-ft. tunnel. Greater lengths of form are being attempted in the 14- and 15-ft. tunnels, but it has not yet been demonstrated that these forms can be successfully filled at any considerable distance from the mixing plant. The 60-ft. forms are usually concreted every third day, or twice each week, and on the average 1 300 ft. of completed arch and side wall in the 14-ft. tunnel have been concreted each month from one plant with three sets of 60-ft. forms. Metal forms of the " Blaw " type are being used throughout, and very satisfactory work is being secured.

Grouting of one portion of the tunnel north of Shaft 13 will shortly begin. This operation consists of first filling the space over the arch resulting from shrinkage and settlement and the inability of the workmen to quite fill the entire section over the key, and later, of forcing grout under high pressure into the seams and crevices of the rock about the lining through deep-seated pipes placed for this purpose wherever, in the periphery of the tunnel, any water appears.

Besides the tunnel concreting, it has been possible on one section to close up three shafts, Nos. 13, 15, and 16, concrete the risers, and at the last two shafts to build the chambers at the top. The equipment for the shafts and chambers is being delivered and installed. Only about half of the connections to the distribution system will be provided for in the present installation.

COST OF THE TUNNEL.

The city tunnel when completed will have cost in the neighborhood of $20 000 000, including the contracts for equipment, and all real estate, engineering, and other expenses.

Preliminary investigations, surveys, borings, etc.....	$361 300
Real estate.....	353 300
Estimated construction, including engineering expenses (approximate).....	19 500 000
Total	$20 214 600

This amount corresponds to a unit price of $216 per foot of tunnel, and in addition to the tunnel itself includes the cost of over 8 000 ft. of waterway shafts, together with the masonry chambers at the surface and the equipment.

CONDUITS OF THE CITY AQUEDUCT.

Beyond the terminal shafts of the city tunnel, pipe conduits are being laid for the supply of the outlying sections of the city. One of these has already been laid of about equal lengths of 66-in. steel and 48-in. cast-iron pipe from Shaft 23 through Brooklyn borough to the water front at The Narrows in Bay Ridge, a distance of 6.3 miles, and is to be continued 3.3 miles farther across The Narrows to Silver Lake reservoir in Richmond borough, a basin of 400 million gallons capacity recently placed under contract. The connection across The Narrows is to be a 36-in. flexible, jointed pipe laid in a dredged trench with a cover of 8 ft. and placed at no point within the pier head lines less than 45 ft. below mean low water. The main from The Narrows to Silver Lake reservoir is to be a 48-in. cast-iron pipe. From Shaft 24, another conduit, 6.3 miles in length, of 66-in. steel and 48-in. cast-iron pipes, is laid out for the supply of Queens borough, and the cast-iron portion, 4.0 miles long, has already been laid from Broadway and Willoughby Avenue, Brooklyn, to the terminus at Queens Boulevard and Fisk Avenue in Queens borough. Frequent connections are being provided on these conduits by which the existing mains of the distribution system may be fed, and regulating valves are planned for all connections with the low service mains.

The conduits already constructed have presented no difficulties

other than those always met in laying large pipes in city streets, and they merit no further description. The total cost of these trunk conduits in the city, including engineering expenses, is estimated at $2 000 000, and Silver Lake reservoir with real estate and engineering $1 200 000 more.

HYDRAULICS OF THE CITY TUNNEL AND CONDUITS.

It will perhaps be of most interest to water-works men to note the volumes of water which may be drawn from the waterway shafts of the city tunnel, and to outline the possibility in the direction of improving the pressures in the distribution system and of furnishing a gravity supply to the high services of the city with the introduction of the Catskill supply.

In designing the outlets for the waterways of this tunnel, it was, of course, impossible to anticipate with any degree of accuracy the amount of water which in the future it may be desired to draw from each shaft, but so far as possible every reasonable use of the tunnel has been provided for. There are 13 shafts, Nos. 2, 4, 5, 6, 7, 9, 12, 14, 15, 16, 19, 21, and 22, which are to have a single riser 48 in. in diameter, as described in the previous pages, and it is estimated that, in proportion to the effective head between the tunnel and the distribution mains, each waterway of this size can discharge from 50 to 100 million gallons per day with a loss of head in the shaft and connections from 2 to 8 ft. At 6 shafts, Nos. 8, 10, 13, 17, 18, and 20, where greater drafts are anticipated, two 48-in. risers are to be installed, and these can discharge, if required, from 150 to 200 million gallons per day under a loss of head estimated at 5 to 9 ft. Two connections of still larger size, 72 in. in diameter, are to be provided at Shaft 3, at the head of the Jerome Park reservoir, and, when necessary, 300 million gallons per day, more than half of the entire Catskill supply, can be diverted into the Croton system at that point. A similar cross connection with the Croton works is made at Shaft 10, where two 48-in. risers are planned and large pipe connections are to be carried to the 135th Street gate-house on Amsterdam Avenue, from which most of the large mains of the Croton system are laid. A supply of 200 million gallons per day can be delivered to the Croton system at this point. The waterways in the two terminal

shafts, Nos. 23 and 24, have also been made of ample size, since upon these shafts will depend the supply of the three boroughs of Brooklyn, Queens, and Richmond. Each of these shafts is to have two 72-in. risers and can discharge the maximum flow through the 11-ft. tunnel leading to Brooklyn, estimated at 300 million gallons per day with less than 4-ft. loss of head. Regulating valves are to be installed at all shafts except Nos. 2, 8, and 9, which are to supply high-service districts alone, and Nos. 23 and 24, which are to feed the high as well as the low services of Brooklyn, Queens, and Richmond boroughs through the large pipe conduits leading from them.

The actual distribution of the Catskill supply will naturally be decided upon by the Department of Water Supply, Gas, and Electricity, which has charge of the operation and maintenance of the existing water works, including the distribution system. It has been suggested that, with 500 million gallons per day of water available from the Catskill services, it might be the policy of the operating department to furnish the Catskill water to all the high-service districts in the boroughs of Manhattan and The Bronx, and entirely supply the boroughs of Brooklyn, Queens, and Richmond, leaving for the low-service zones in Manhattan and The Bronx the supply from the present sources. This policy would result in great economy to the city, inasmuch as it would permit of supplying the city almost entirely by gravity and of shutting down most of the pumping stations now in operation, including those of the ground-water works on Long Island and Staten Island, until the increase in the consumption of water in the city again required the water from these works. On the basis of some such distribution of the Catskill supply as suggested above, the probable gradient in the city tunnel has been worked out to show what pressures will be available in each section of the city. For this computation a flow equivalent to 575 million gallons per day, or 15 per cent. in excess of the average delivery of 500 million gallons per day, has been assumed for the hours of maximum consumption

The deliveries assumed for each of the tunnel shafts are, of course, purely speculative, as any number of assumptions of this kind can be made, depending upon the future growth and con-

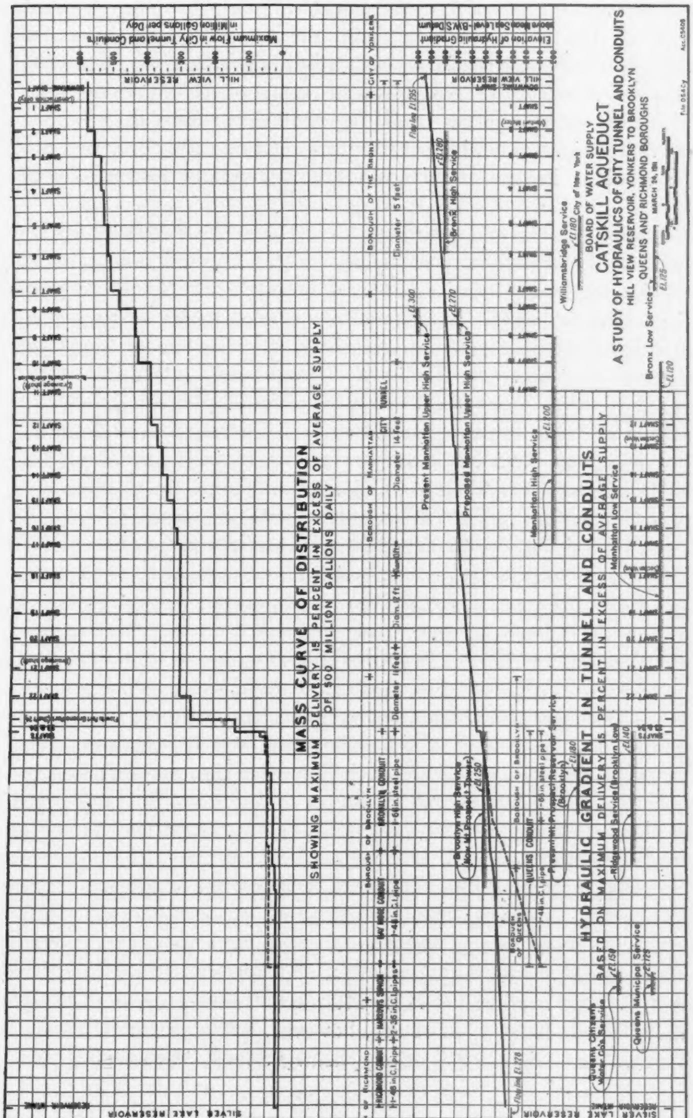

MASS CURVE OF DISTRIBUTION
SHOWING MAXIMUM DELIVERY 15 PERCENT IN EXCESS OF AVERAGE SUPPLY
OF 500 MILLION GALLONS DAILY
HYDRAULIC GRADIENT IN TUNNEL AND CONDUITS
BASED ON MAXIMUM DELIVERY 15 PERCENT IN EXCESS OF AVERAGE SUPPLY
BOARD OF WATER SUPPLY
CATSKILL AQUEDUCT
A STUDY OF HYDRAULICS OF CITY TUNNEL AND CONDUITS
HILL VIEW RESERVOIR, YONKERS TO BROOKLYN
QUEENS AND RICHMOND BOROUGHS
HILL VIEW RESERVOIR
SILVER LAKE RESERVOIR
CITY TUNNEL

FIG. 4.

sumption in each portion of the city, the limits which may be fixed between the various services, and the disposition of the water from the present works. The distribution made gives, however, as severe a test of the capacity of the tunnel as is likely to be made. The assumed discharges from the shafts are shown in the mass curve on Fig. 4, on which is also drawn the corresponding hydraulic gradient in the tunnel and trunk conduits leading therefrom.

The high and Williamsbridge services in The Bronx, the high and the upper high services in Manhattan borough, and a small portion of the low services in these boroughs are provided for in this estimate, and it is assumed that the districts in Brooklyn, Queens, and Richmond now served by the city's water works are entirely supplied. No discharge is assumed for the lower shafts in Manhattan Borough, though some will doubtless be drawn at these shafts for the downtown business districts and ample provision has been made for serving them in constructing the shafts. The effect of diverting to these Manhattan shafts some of the flow estimated for Brooklyn Borough would, of course, result in raising the tunnel gradients above that estimated.

From the diagram it may be seen that on the distribution for the Catskill supply that has been here assumed, the average gradient in the city tunnel between Hill View reservoir and Brooklyn is 2 ft. to a mile. With the water in Hill View reservoir at Elevation 295 (B. W. S. datum, mean sea at Sandy Hook), which is 1 ft. below the normal flow line, the gradient in the tunnel within the borough of the Bronx is from Elevation 280 to Elevation 290, which is quite high enough to supply the high services in that borough, giving an average pressure of about 50 lb. per sq. in. in the Bronx high service, and 70 lb. per sq. in. in the Williamsbridge service.

Similarly, the tunnel gradient in Manhattan varies from Elevation 280 at the Harlem River to about Elevation 260 at the southerly end of the island, which corresponds to a pressure of about 70 lb. per sq. in. in the Manhattan high service and about 40 lb. per sq. in. in most of the Manhattan upper high service. Several acres in the latter district are, however, too high for the tunnel gradient and will have to be supplied by a local " booster" station

or from one of the present pumping stations of the Croton system. In lower Manhattan Borough the estimated tunnel gradient is sufficiently high to raise the water to the sixteenth floor of the higher buildings and to give an average pressure at the curb of about 100 lb. per sq. in.

In Brooklyn Borough the hydraulic gradient is estimated from Elevation 255 to Elevation 260, falling off in the large trunk conduits leading from Shafts 23 and 24 to Elevation 240, within the limits of the borough. This gradient is high enough to deliver water to a level slightly above the present intermediate or Mt. Prospect Reservoir service, giving an average pressure of about 60 lb. per sq. in. in that service, and to supply the high service at a somewhat lower gradient than now, taking care of the entire service with the exception of a few isolated areas, to which it may be necessary to pump. Some reduction in pressure would doubtless be made at the connections with the mains of the low or Ridgwood service.

The gradient estimated in the Queens conduit is ample to supply the districts now occupied in Queens Borough, and the gradient in the conduit to Richmond Borough is sufficiently high to deliver a supply to the new Silver Lake reservoir at Elevation 230, which is intended to serve the entire borough with the exception of the higher hills.

Considering the smooth, even surface which is being secured on the tunnel lining, the value of 120 assumed for " C " in the Chezy formula in working out this gradient is conservative, and it is quite possible with the flows here assumed that for many years the gradient in Brooklyn would at least be 5 or 6 ft. higher than estimated, corresponding to a value of " C " of 130.

Aside from the great economy effected by the tunnel plan and the gain to the city and the public in avoiding the laying of large mains in busy streets of the city, it is evident, from a consideration of the design and construction of the city tunnel and of its possibilities in the direction of improved service, that this tunnel has immeasurable advantages over a system of pipes, in that the tunnel is a permanent structure, not exposed to injury from construction work in the streets, and its capacity is such that it will make available to all sections of the city a continuous supply

of water in large volumes and at ample pressure for fire protection as well as for domestic and industrial uses.

Among the many notable engineering problems that have been worked out on the Catskill Aqueduct under the direction of our president as chief engineer of the Board of Water Supply, not the least in brilliancy of conception and boldness of design is this plan for the distribution of the Catskill water to all parts of New York City.

DISCUSSION.

MR. LAZARUS WHITE.* The chief progress that has been made in this type of construction is due to the improved method of shaft sinking, for the tunnels connect the bottoms of shafts, and they have to be sunk before the tunnels can be started. Five or six years ago sinking shafts was thought to be a very serious matter; and as there had not been deep shafts of this character sunk in this part of the country, there was a great deal of exaggeration as to their cost.

At the time we started to work on the first tunnel of this character on the Catskill Aqueduct, the shafts were all timber-lined, the timber in the waterway shafts being subsequently taken out and concrete lining put in. About that time a method of sinking concrete shafts without the use of timbering came into use in the coal regions and was adopted in the later siphons. In this method the shafts were sunk in stretches of about a hundred feet, and immediately lined with concrete, which protected the sides from caving and subsequently became a waterway. This method proved to be much more economical than taking the timbering out and putting the concrete in, and it was adopted later even in shafts which were not waterway shafts, and shafts which were expected to be in use for only a few years.

Due to the great number which were sunk, considerable improvements were made in the art of shaft sinking, so that these concrete-lined ones were sunk at several times the speed that it was originally supposed could be made. In one case the shaft was sunk 200 ft. and completely lined in less than three months, and in some cases 700 ft. were sunk in about one year, — even

* Division Engineer, Manhattan Division of the Catskill Aqueduct.

where the tops of the shafts had to be started with compressed air caissons.

Besides improvement in speed, another perhaps even greater improvement was originated here in connection with shafts where water was encountered. These had previously proven to be very expensive, for every time work was stopped to blast, the water accumulated and had to be pumped out, making the work very slow and difficult. A method was learned, however, by which the water could be cut off as the shaft went down piecemeal, by lining the shaft with about two feet of concrete and injecting cement grout into water-bearing seams. In this way the shafts were kept practically dry and safe to the bottom, almost regardless of the amount of water encountered. Of course there was some slowing up in progress, but not very much. A concrete-lined shaft can now be sunk, at a rough estimate, for about $200 a foot.

In one of our first timber-lined shafts before this method had been well worked out, there was a great deal of delay caused by encountering quantities of water. One of our contractors said he could have saved several hundred thousand dollars in the sinking of a similar shaft if this method had been known.

When you have overcome the problem of shaft sinking, the rest of it is comparatively simple. You practically make the conditions to suit yourself, by the depth of shaft and by exploring the ground. Pressure tunnels can run up and down at any angle to get from shaft to shaft, and you can pick out the more favorable rocks for tunneling. I believe that this type of construction will be used more and more, particularly where pipe lines under great heads would otherwise be laid. That is, in case of a deep and broad valley these tunnels compare more and more favorably with steel pipe lines.

New York City can fairly claim the credit of originating this type of construction on a modern and large scale. It was first used in the new Croton aqueduct under the Harlem River about thirty years ago. The application of it for distributing water is entirely new; it is the adaptation of a pressure tunnel and a siphon tunnel to the conduit line. It has, I think, worked out wonderfully well.

There has been one case in the West, which you probably recall,

where there was some trouble with a tunnel of this character, but if you will examine that case you will see that that tunnel was a sort of a halfway measure; it was a cross between a steel pipe line and a tunnel of this character. It was started several years ago, when the method had not been well worked out even here. We know very well that the way to cross a valley is not by sinking an incline at each side and then coming out at the bottom, but by sinking vertical shafts and then driving a tunnel nearly horizontally between them. I believe that if that tunnel had been driven in that way they would not have encountered any trouble.

THE ADDITIONAL WATER SUPPLY FOR THE CITY OF PITTSFIELD, MASS.

BY HIRAM A. MILLER, CONSULTING ENGINEER.

[*Read September 10, 1913.*]

EXISTING WATER SUPPLY.

Previous to the construction of the additions to the Pittsfield water supply, to be described in this paper, the water works consisted of a gravity system from four watersheds east of the city in the towns of Dalton, Hinsdale, and Washington; the water being taken from small intake reservoirs on Sackett, Hathaway, Ashley, and Mill brooks. Near the headwaters of Ashley Brook is a natural lake called Ashley Lake, which had been made into a large storage reservoir by the construction of a dam across Ashley Brook, its outlet; but which, on account of its small watershed, if drawn down to the limit of only its gravity capacity, would require two or more years to fill again. The storage from this lake passes down Ashley Brook into the intake reservoir below. (Plate XXI.)

These four intakes are at different heights, the elevation of the overflow varying from Elevation 1249 of the one on Ashley Brook to Elevation 1340 of the one on Mill Brook.

The areas of the different watersheds above the points of taking the water are as follows:

Sackett	1.76 sq. miles
Hathaway	1.05 sq. miles
Ashley, below Ashley Lake	1.75 sq. miles
Ashley Lake Watershed*	.72 sq. miles
Mill	1.77 sq. miles
Total	7.05 sq. miles

The capacities of the reservoirs are as follows:

Sackett	2 000 000 gal.
Hathaway	1 000 000 gal.
Ashley	23 000 000 gal.
Ashley Lake	409 000 000 gal.
Mill	14 000 000 gal.

* Including Ashley Lake.

It was estimated that the available water supply from the above sources in a series of dry years would be 2 650 000 gal. per day.

The supply mains leading into the city consisted of a 12- and 16-in. cast-iron pipe from Ashley intake, with a 10-in. pipe from Hathaway intake and another of the same size from the Sackett intake, joining these pipes. There was also a 12-in. pipe from the Mill Brook intake joining the 12- and 16-in. pipes from Ashley intake near the southerly edge of the settled portion of the city.

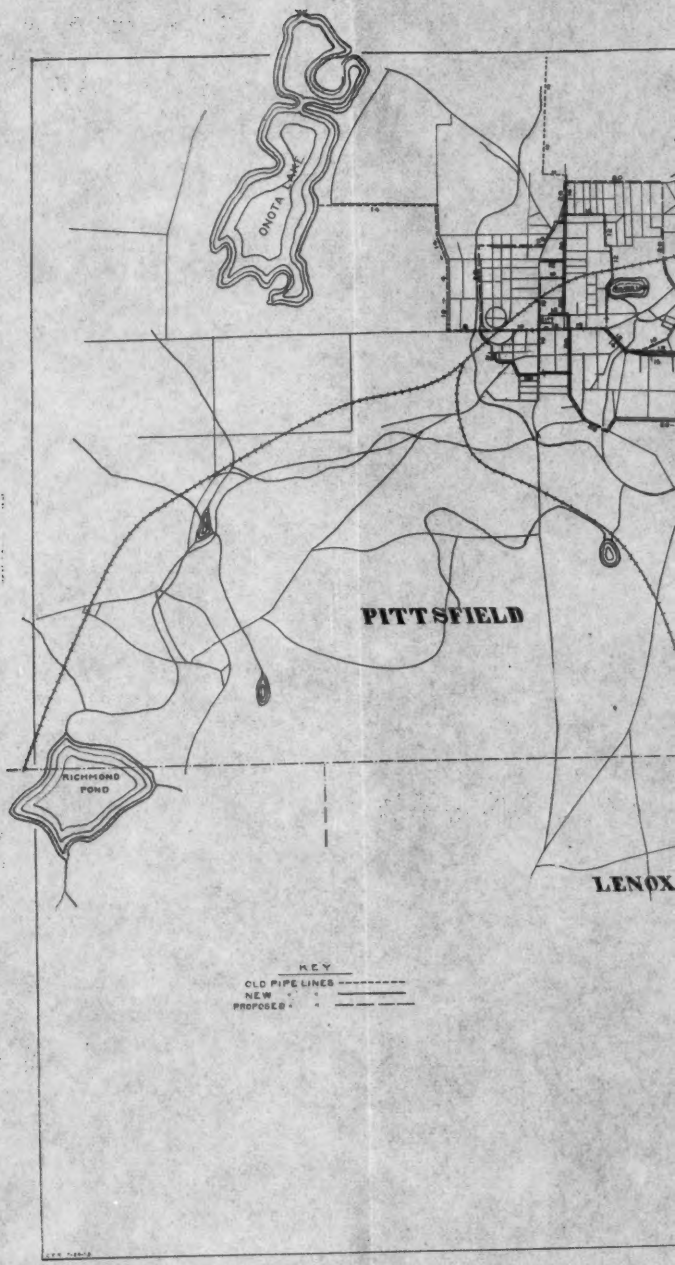
The static pressure at City Hall, with the Ashley intake reservoir full, is 86 lb.

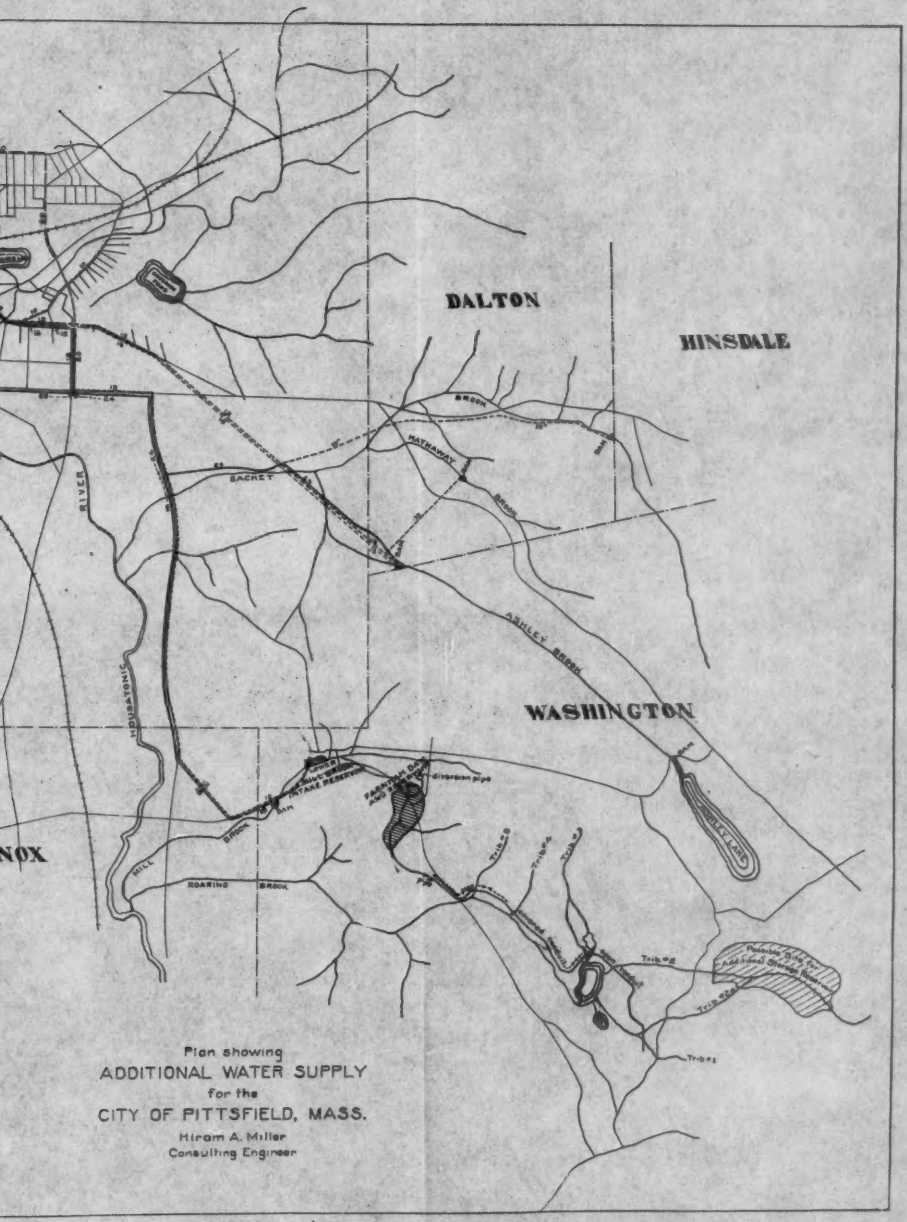
It had been known for some years that the city was rapidly outgrowing its water supply. In 1908 the consumption was estimated to be 2 500 000 gal. per day, and in 1909 it had increased to 2 800 000 gal. per day, notwithstanding the most stringent measures were taken to keep the consumption down. In order to make up for the deficiency of the water supply, a small dam was constructed in the fall of 1908 on Roaring Brook, a stream to the south of Mill Brook, and the water diverted through a wooden flume into the Mill Brook watershed. A pump was also installed at Ashley Lake to pump the water from the lake when the water fell below the level at which it would flow by gravity through the sluice gate in the Ashley Lake dam. In 1909 a pumping station was installed at Onota Lake in the northwestern part of the city, from which water was pumped into the mains. The consent of the State Board of Health to the temporary use of the Onota Lake water had been obtained.

The distributing mains were also small, the largest being 12 in. in diameter, so that pressures generally throughout the city were quite low.

PROPOSED EXTENSIONS.

The only available sources for an additional water supply were Onota Lake referred to above, Richmond Pond southwest of the city, and Roaring Brook above the point where it could be diverted into the Mill Brook watershed. This last-mentioned source of water supply seemed especially desirable as it would be a gravity supply, while the water from the lakes would require pumping, and consequently this source of water supply was decided upon.


ONOTA LAKE
PITTSFIELD
RICHMOND POND
LENOX
KEY
OLD PIPE LINES
NEW " "
PROPOSED " "


DALTON
HINSDALE
WASHINGTON
NOX
BACHET
RIVER
ROARING
BROOK
Plan showing
ADDITIONAL WATER SUPPLY
for the
CITY OF PITTSFIELD, MASS.
Hiram A. Miller
Consulting Engineer

Surveys and investigations of this water supply had been made in 1908 and 1909.

Permission had been obtained from the State Board of Health to use certain tributaries of Roaring Brook for a permanent water supply, as it was deemed undesirable to take the water directly from Roaring Brook, as the water flowed through a large pond, the bottom of which was composed of muck from five to thirty feet deep and was surrounded on all sides by swamp areas, the soil of which was principally muck. Additional supply mains were to be built into the city, and additional distribution mains through the city.

DAM.

It had originally been intended to construct a reservoir with an earth dam on Mill Brook about three thousand feet above the Mill Brook intake, and divert two of the tributaries (No. 4 and No. 5) of Roaring Brook into this reservoir; the reservoir to have a storage of from one hundred fifty to two hundred fifty million gallons; then, later on, to construct an additional storage reservoir on the largest of the tributaries of Roaring Brook, known as tributary No. 2, and divert this tributary and No. 1 and No. 3 into the Mill Brook watershed. Further investigations lead to the conclusion that it would be better to construct a higher dam of masonry and impound a larger quantity of water, particularly as investigations at the site of the proposed reservoir on tributary No. 2 of Roaring Brook showed that two dams would be necessary instead of one, and also that there would be a large area of shallow flowage. It was, therefore, finally decided to erect a dam of cyclopean masonry with concrete blocks on the upstream face (to be called the Farnham Dam, in honor of the engineer of the board of public works of the city) about 100 ft. high above the bed of the brook, with a spillway at Elevation 1585, and the top of the dam at Elevation 1595, impounding, as estimated, 442 000 000 gal., which would at least be nearly as much storage as the area of the watershed tributary to the reservoir would warrant; to construct a diversion conduit along the northeasterly side of Roaring Brook, diverting all five of its tributaries into the Farnham Reservoir; to construct a small diversion conduit from one of the tributaries of Mill Brook

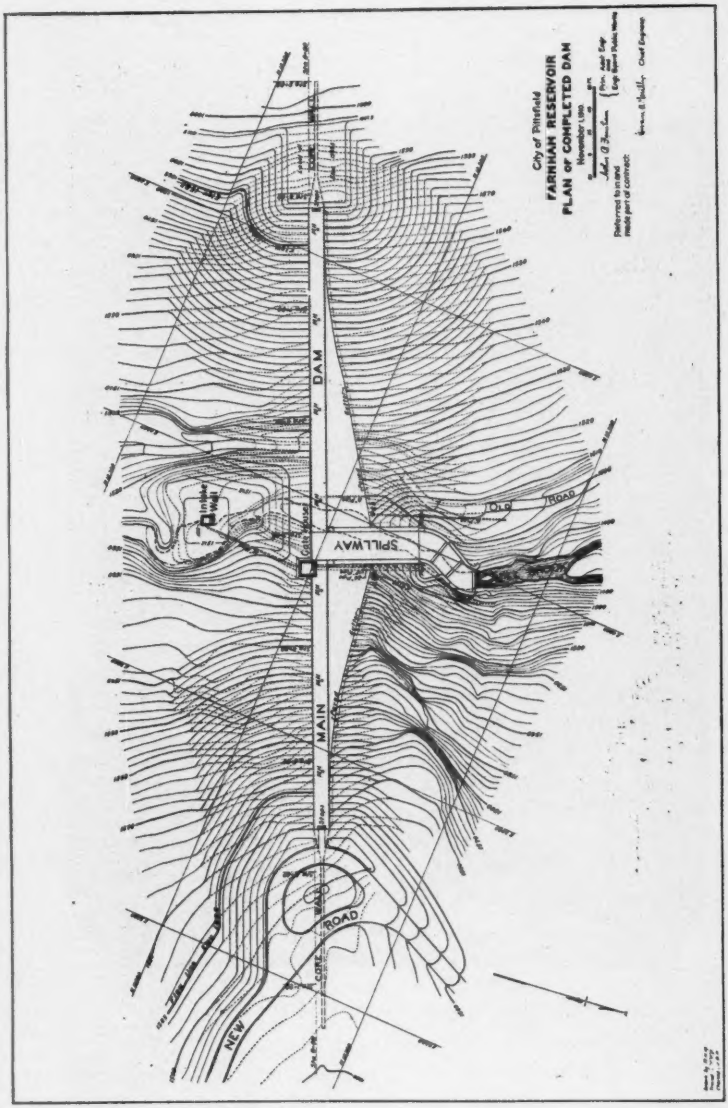

City of Pittsfield
FARNHAM RESERVOIR
PLAN OF COMPLETED DAM
DAM
SPILLWAY
MAIN
NEW
ROAD

FIG. 1.

DAM UNDER CONSTRUCTION.

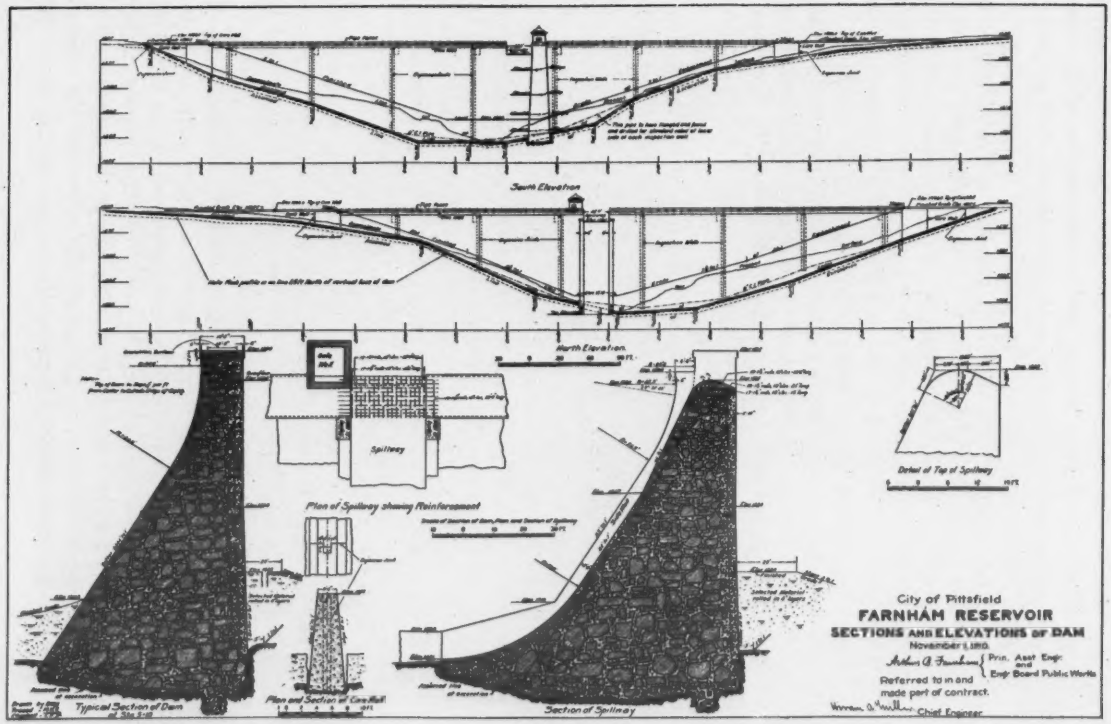

South Elevation
North Elevation
Spillway
Plan of Spillway showing Reinforcement
Detail of Top of Spillway
Typical Section of Dam
Plan and Section of Cut-off
Section of Spillway
City of Pittsfield
FARNHAM RESERVOIR
SECTIONS AND ELEVATIONS OF DAM
November 1, 1910.
Arthur A. Fraunhaus { Prin. Asst. Engr. and Engr. Board Public Works
Referred to in and made part of contract.
Chief Engineer.

FIG. 2.

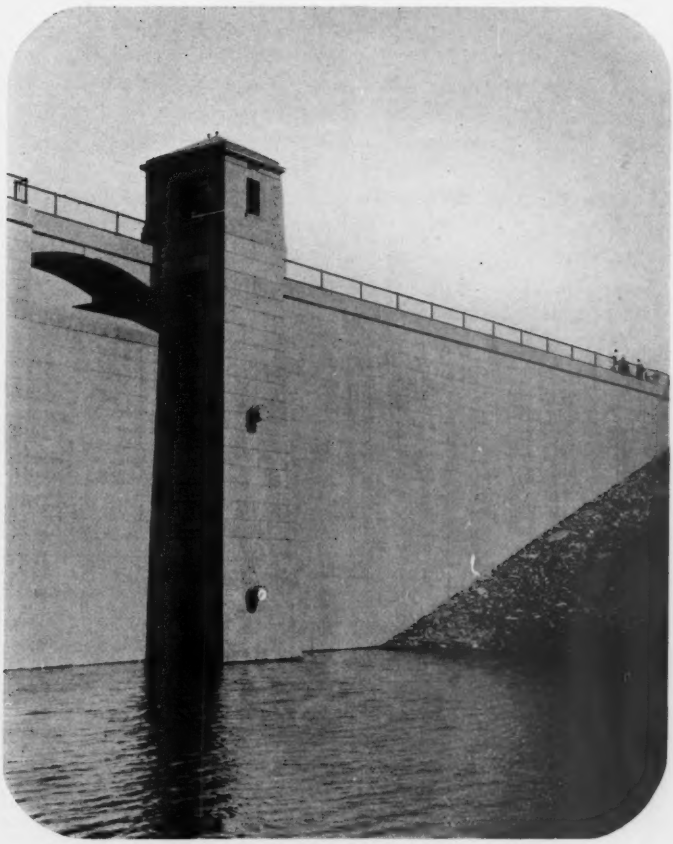
into the Farnham Reservoir; and also to construct large supply and distribution mains; leaving further consideration of the reservoir on tributary No. 2 of Roaring Brook until such time as the city would need to investigate farther additions to its water supply.

Test pits and other investigations showed that the foundation of the dam would be mainly rock of an unusually good quality of schist running into Cheshire quartzite at the westerly end of the dam. There was a large outcrop of quartzite a short distance above this end of the dam, so that the cyclopean stones and the coarse aggregates for the masonry would be easily available. It was thought probable that this quartzite could be crushed by sand rolls into material suitable for fine aggregates, or failing in that there were apparently large quantities of sand in the Housatonic Valley about three miles from the site of the dam which appeared to be satisfactory.

The dam has a gravity section, about 600 ft. in length, with core walls at each end, making the total length of the dam about 900 ft. It is divided by expansion joints with inspection wells passing down through the joints, near the upstream side, to the bottom of the dam. These inspection wells are connected at the bottom by cast-iron drainage pipes, with a pipe leading from the bottom of the deepest well to the westerly side of the lower end of the spillway.

The gate well is on the upstream side of the dam outside the regular section, and is about 10 ft. square, having four inlets at various elevations, the lower one consisting of a 12-in. pipe with one gate valve, the others of 20- or 24-in. pipes, having two gate valves on each pipe. On the downstream side of the gate well are one 24- and one 12-in. cast-iron pipe lines leading into a pool on the easterly side of the lower end of the spillway, each having sluice gates in the gate well. The valves and gates are controlled by operating stands in a gate house over the well.

The expansion joints are 80 ft. apart, having 6-in. vertical offsets, 8 ft. apart through the dam. There is a copper strip across the joints on the upstream side of the inspection well similar to the one designed by the engineers of the board of water supply of New York City for the Kensico Dam. One side of the expansion joint is constructed of concrete blocks; on the other side the concrete of the cyclopean masonry is permitted to come to the joint. Be-



DAM.
UPSTREAM VIEW. SPILLWAY AND GATEHOUSE.

fore laying the concrete the side of the joint first constructed was coated with hot tar pitch, then a sheet of roofing paper was applied to the hot pitch, and the roofing paper was again coated with hot pitch.

During the last of February of the present year, after the coldest spell of the winter, when the reservoir was full, the total leakage through the joints measured at the end of the drainage pipe was at the rate of 18 000 gal. per day, which had decreased during the present summer to 200 gal. per day when the reservoir was drawn down 11 or 12 ft. Moisture appears on the downstream side of the dam to the extent that a large proportion of the area appears wet on a damp morning, but in a sunshiny afternoon the surface is mainly dry.

The specifications for the dam provided for three classes of mass concrete, of concrete blocks, and of cyclopean masonry, depending on the mixture of the concrete. Class *A* was concrete consisting of one part cement, two parts fine aggregates, and four parts coarse aggregates, with no stones larger than two inches in their greatest dimension. Class *B* was concrete consisting of one part cement, two and one-half parts fine aggregates, and four and one-half parts coarse aggregates, with no stones larger than two and one-half inches in their greatest dimension. Class *C* was concrete having the materials in the proportion of 1:3:6, with no stones larger than three inches in their greatest dimension. Class *D* was to have the same proportions as Class *A*, but to have no stones larger than ¾ in. in their greatest dimension.

It was expected that Class *A* concrete would be used in the lower portion of the dam, and in the lower portion of the gate-house; that Class *B* concrete would be used in the main portion of the dam above where the Class *A* concrete was to be used, up to Elevation 1585, the elevation of the spillway; that Class *C* concrete should be used between Elevation 1585 and Elevation 1595, the elevation at the top of the dam, and that Class *D* concrete was to be used for filling spaces around the copper strips in the expansion joints.

It was further specified that the proportion of fine to coarse aggregates in any of the classes of concrete might be varied so as to reduce the voids to a minimum.

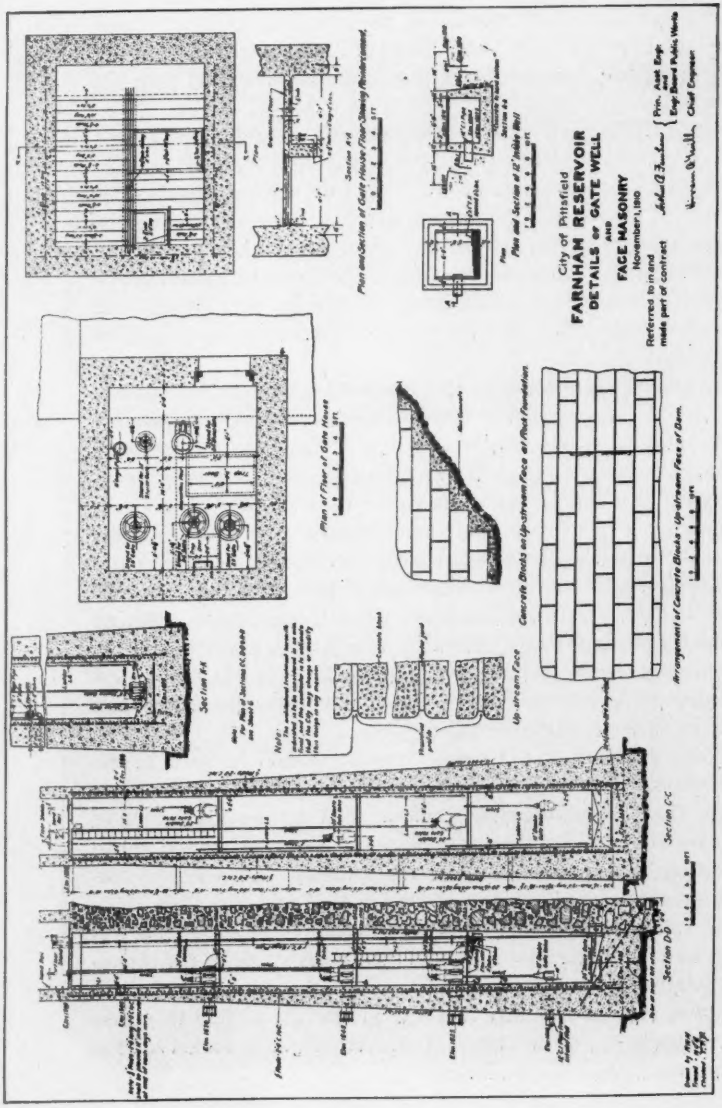

City of Pittsfield
FARNHAM RESERVOIR
DETAILS OF GATE WELL
AND
FACE MASONRY
November, 1900
Referred to in and made part of contract
Plan and Section of Gate House Floor Showing Reinforcement
Plan and Section of 12" Intake Well
Plan of Floor of Gate House
Concrete Blocks on Up-stream Face at Rock Foundation
Arrangement of Concrete Blocks - Up-stream Face of Dam.
Section EE
Section DD
Up-stream Face

FIG. 3.

FIG. 1.
COMPLETED DAM. LOOKING WEST.

FIG. 2.
RESERVOIR PARTLY FULL.

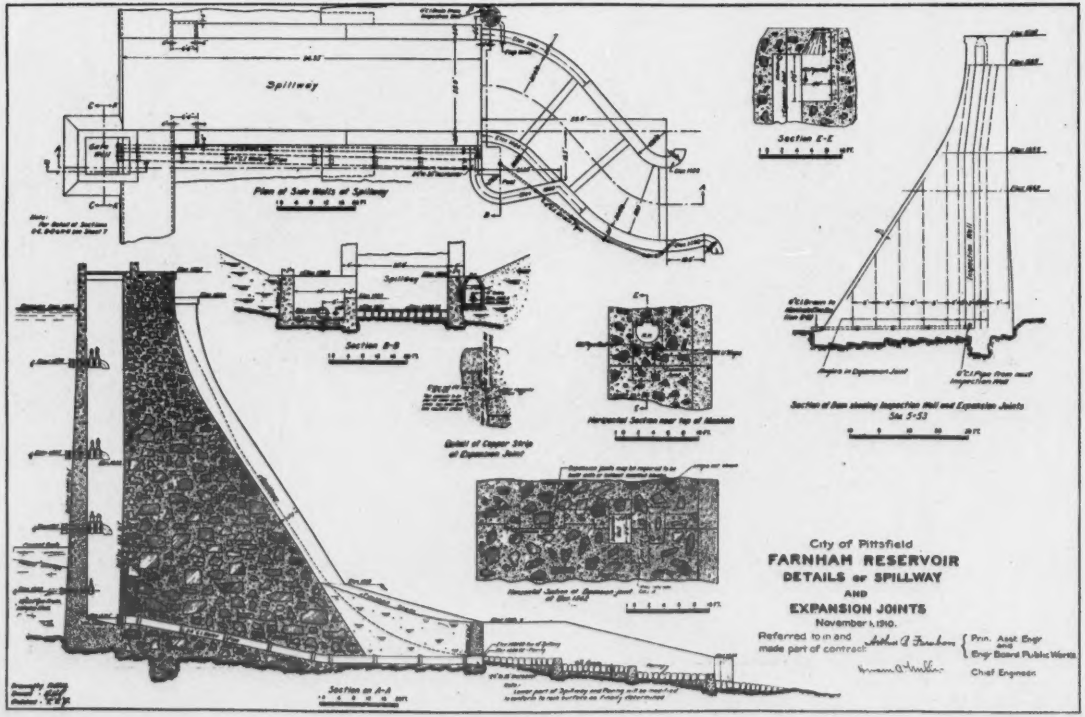

Spillway
Plan of Side Walls of Spillway
Section E-E
Section B-B
Section on A-A
Section of Dam showing Inspection Wall and Expansion Joints
Horizontal Section near top of Abutment
Gutter of Copper Strip at Expansion Joint
City of Pittsfield
FARNHAM RESERVOIR
DETAILS of SPILLWAY
AND
EXPANSION JOINTS
November 1, 1910.
Referred to in and made part of contract
Prin. Asst. Engr and Engr Board Public Works
Chief Engineer

FIG. 4.

The contractor's plant consisted of the usual machinery for quarrying, crushing stone, mixing concrete, placing masonry, and so forth, and had in addition rolls for crushing stone for use in the place of sand for the fine aggregates. The rock from the

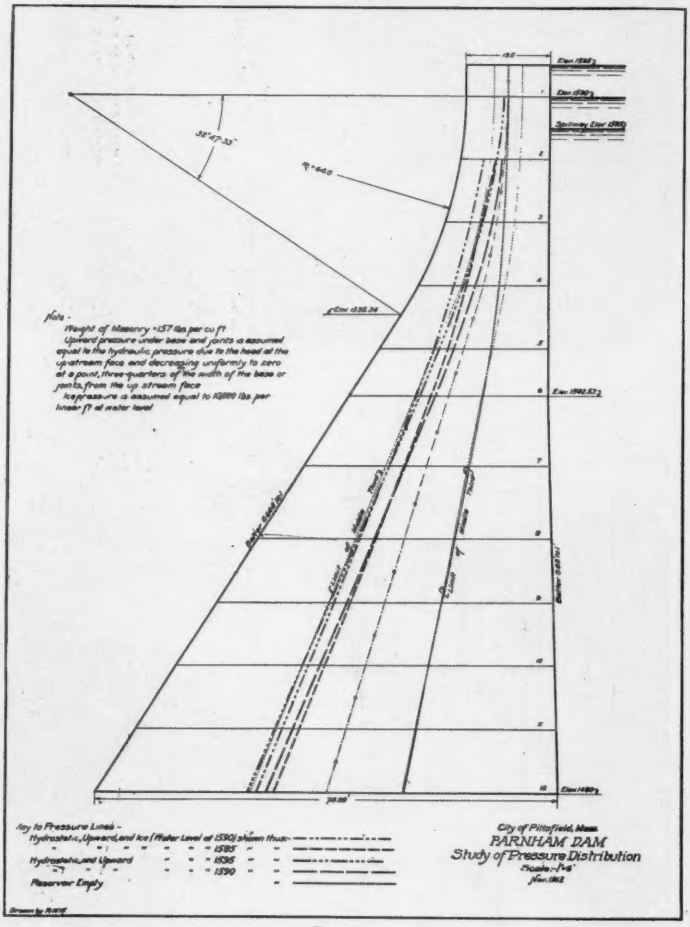

Note -
Weight of Masonry =157 lbs per cu ft
Upward pressure under base and joints is assumed equal to the hydraulic pressure due to the head at the up-stream face, and decreasing uniformly to zero at a point, three-quarters of the width of the base or joints, from the up stream face
Ice pressure is assumed equal to 10000 lbs per linear ft at water level
Key to Pressure Lines -
Hydrostatic, Upward, and Ice (Water Level at 1590) shown thus:
Hydrostatic and Upward
Reservoir Empty
City of Pittsfield, Mass.
PARNHAM DAM
Study of Pressure Distribution
Nov. 1912

FIG. 5.

FIG. 1.
SPILLWAY FROM ABOVE.

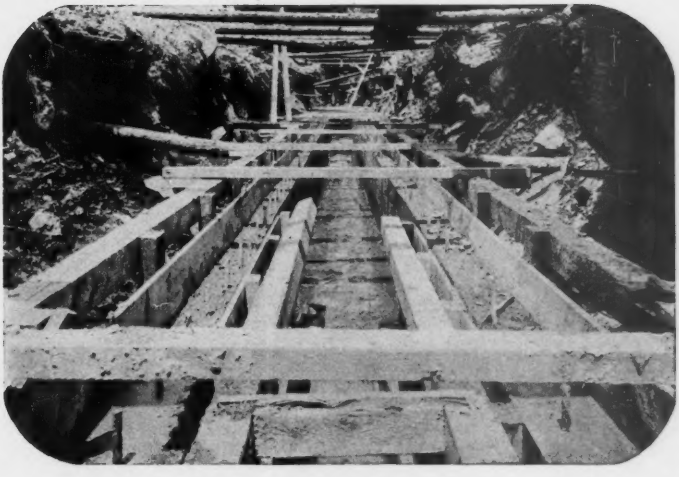


FIG. 2.
DIVERSION CONDUIT. SIDE WALLS LAID.

quartzite ledge above referred to, crushed in the sand rolls, was too fine for the fine aggregates. About one half of that portion of it which would pass through a sieve having 8 meshes to an inch would pass through a No. 100 sieve, whereas the specifications required that of the material passing through a sieve with eight meshes to an inch, not more than 12 per cent. should pass through a No. 100 sieve. There was a schist ledge a short distance from the quartzite ledge which consisted of a very fine dense rock weighing 174 lb. per cu. ft., which was better in this respect but not enough so to comply with the specifications.

Careful tests, however, were made to determine both the permeability and strength of concrete and mortar made from mixtures of aggregates from the quartzite and the schist having different proportions of the very fine material, and it was found that with fine aggregates, having a very large proportion of particles which would pass through a No. 100 sieve, the concrete was as strong and as impervious as the concrete made with fine aggregates which only had 12 per cent. that would pass through a No. 100 sieve, and that the 1:3:6 mixture was as impervious as the 1:2:4 mixture. The contractor was, therefore, permitted, provided he would use three skips of the schist rock to one skip of the quartzite rock in his concrete, to use the fine aggregates when the proportion which would pass through a No. 100 sieve would not exceed 40 per cent. of the total which would pass through a sieve with eight meshes to the inch; and Class *C* concrete, concrete blocks, and cyclopean masonry, with the increased fine material in the fine aggregates, was used, as provided in a clause in the contract reserving to the city the right to substitute one class of masonry in the dam for another even to the exclusion of some of the classes, throughout the dam almost entirely where in the preliminary quantities Class *B* concrete, concrete blocks, and cyclopean masonry had been estimated.

In the revised pressure diagram, Fig. 5, made since the completion of the dam, the weight of the masonry is taken as 157 lb. per cu. ft., the volume of the inspection wells being included in the volume of the dam, the weight of the quartzite being 169 lb., and the weight of the schist 174 lb. The weight of the concrete was averaged at 151.2 lb.

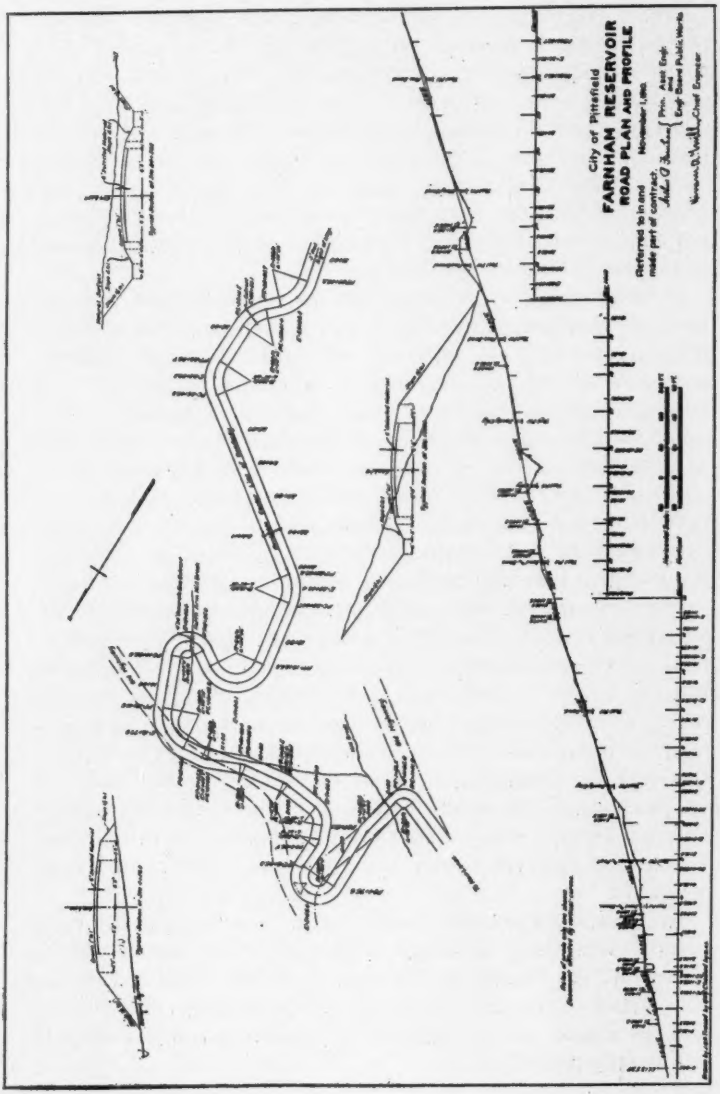

City of Pittsfield
FARNHAM RESERVOIR
ROAD PLAN AND PROFILE
November, 1901.
Referred to in and
made part of contract.
Pres. Asst. Engr.
and
Engr. Board Public Works
Chief Engineer

FIG. 6.

Ice pressure was taken at 10 000 lb. per linear foot at the surface of the water. It was assumed that the upward pressure of water under the dam would be equal to the full pressure of the water at the upstream side, and that it would be nothing at three quarters of the distance from the upstream side to the downstream side, either at the bottom of the dam or at any horizontal section of the masonry. The pressure diagram, when the reservoir is empty, shows that the pressure line passes about three inches outside of the middle third, but if the deduction for the inspection wells had been taken out of the vertical longitudinal section in which they are, instead of being distributed through the total volume of the dam, and if the lesser weight of the masonry near the upstream face of the dam (being all concrete) had been taken into account, this pressure line would not have passed outside the middle third. The diagram shows that the pressure will keep within the middle third, in accordance with the above assumptions when the reservoir is full to Elevation 1585—the elevation of the spillway. It will also keep within the middle third with the water at Elevation 1590, provided there is no ice pressure, consequently flashboards 5 ft. high can be safely placed across the spillway, provided they are removed before ice forms on the surface of the reservoir to any great thickness; and provided also that there is no depth of water passing over the spillway.

NEW ROAD.

As the public road passed across the site of the dam and through the site of the reservoir, a new location was made around the easterly side of the dam and along the easterly side of the reservoir. As this was mainly on the steep hillside, a large portion of the construction consisted of excavating on one side of the roadway and depositing the material on the other. (Fig. 6.)

In order to keep the grade down to 8 per cent. it was necessary to pass up one side and along the other side of two streams to get sufficient development.

RESERVOIR.

The area of the reservoir, Fig. 7, is about 42 acres. From this area and for a short distance in height above the flow line, the

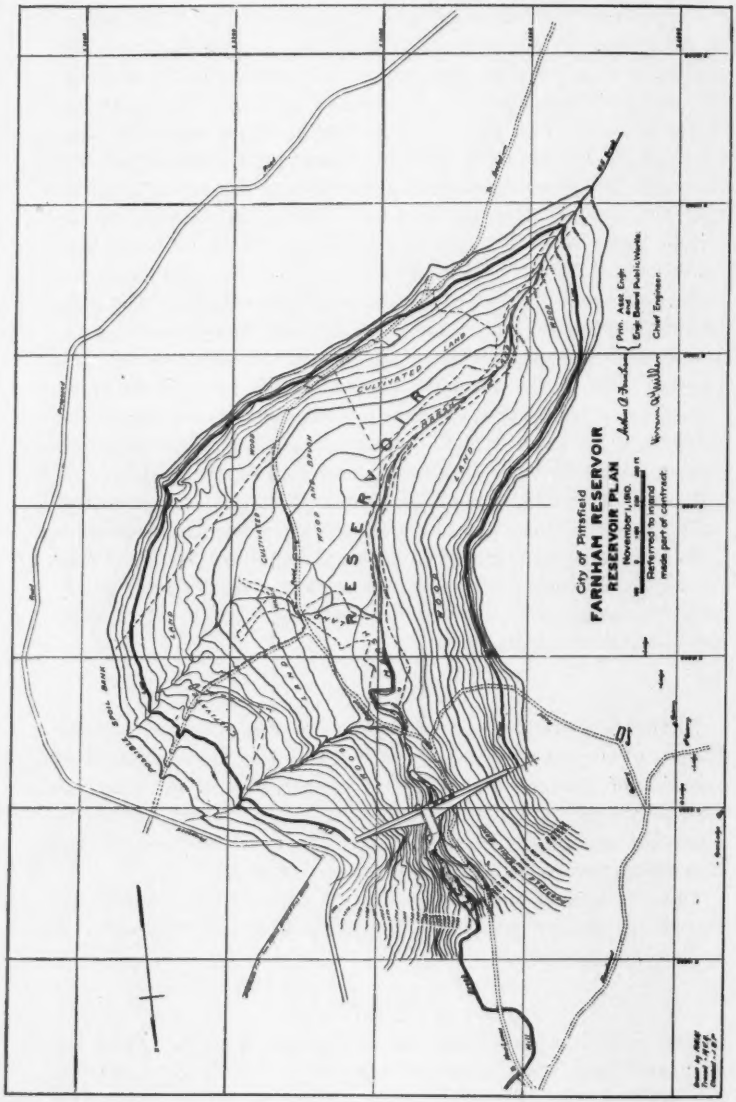

City of Pittsfield
FARNHAM RESERVOIR
RESERVOIR PLAN
November 1, 1910.
Referred to inland
mase part of contract
Prin. Asst. Engr.
Engr. Board Public Works
Chief Engineer
RESERVOIR
CULTIVATED LAND
WOOD
PASTURE
ROAD
BROOK
DAM

FIG. 7.

soil was entirely removed, except that on an area in the bottom of the reservoir the muck was covered by additional soil and the whole covered with earth taken from the reservoir after the soil had been removed.

The reservoir will contain, below the elevation of the spillway, as measured after the soil had been removed, 446 500 000 gal., and with 5 ft. of flashboards on the dam will contain about 517 500 000 gal.

DIVERSION CONDUITS.

A diversion conduit, Fig. 8, was constructed from a branch in Mill Brook, called Monument Brook, to divert the water from this brook into the proposed reservoir, and a diversion conduit was carried from the Mill Brook watershed along the side of Roaring Brook, and the pond above referred to, intercepting tributaries Nos. 1, 2, 3, 4, and 5, to divert the water from this portion of the Roaring Brook watershed into the reservoir. These conduits were designed to have a capacity of not less than six and one-half million gallons per square mile of watershed tributary to them. Twelve-inch sewer pipe was used for the conduit from Monument Brook. The lower portion of the Roaring Brook conduit is covered and the upper portion is open.

Where it was necessary to have the covered conduit larger than a 24-in. pipe, the conduit consists of a reinforced concrete box, the thickness of the concrete being five or six inches, depending upon the size of the box.

Inlets were provided where required at the side of the covered conduit to admit the run-off from the tributary brooks and from the hillsides. At each inlet and at the upper end of the covered conduit, settling basins were constructed. Where the covered conduit turns away from Roaring Brook a waste gate was provided to permit the water flowing in the conduit to discharge into the brook when desirable.

Where the covered conduit was below the lowest ground water surface, pipes were laid with open joints, or in the case of the concrete box, 2-in. pipes were inserted at frequent intervals in the sides of the box, just above the bottom, for the purpose of leading the ground water into the conduit.

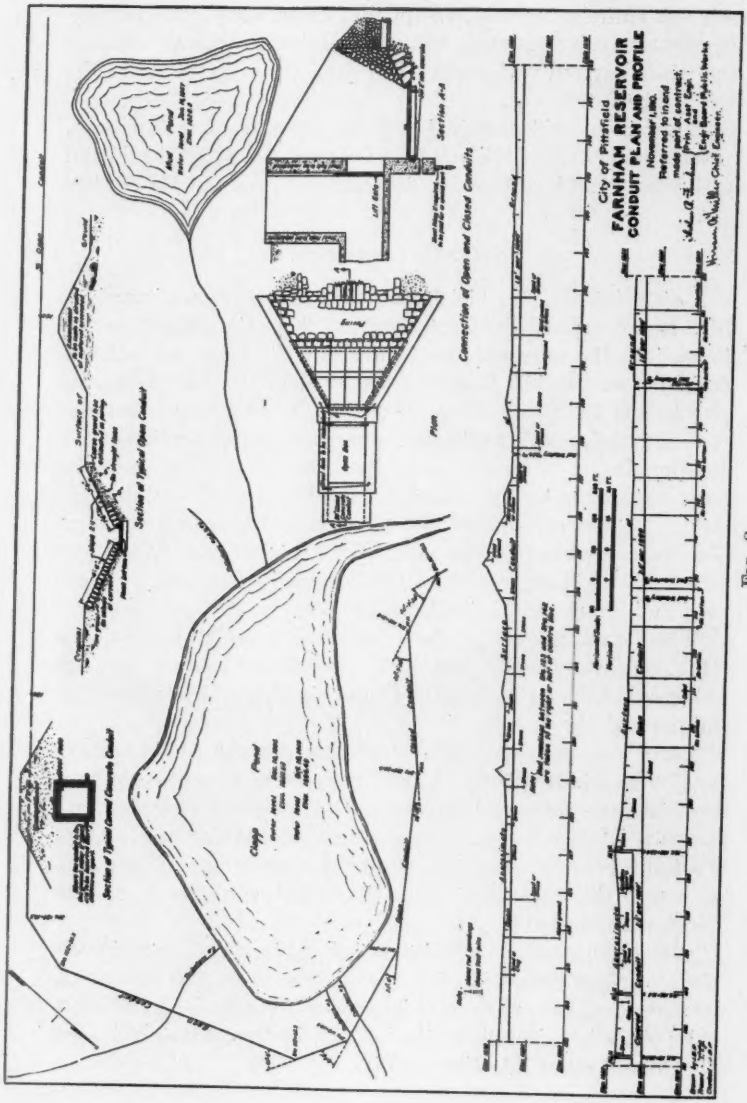

City of Pittsfield
FARNHAM RESERVOIR
CONDUIT PLAN AND PROFILE
Connection of Open and Closed Conduits

FIG. 8.

FIG. 1.
OUTLET OF DIVERSION CONDUIT.

FIG. 2.
OPEN DIVERSION CONDUIT.

The open conduit consisted of a ditch with two to one slopes on the sides, lined on the bottom with a plank 12 in. wide, on each side of which was the half of a four-by-four scantling sawed diagonally. The sides of the ditch were paved for a distance above the bottom.

Small open-side conduits were constructed at three points on the main open conduit through the swamp to the foot of the hills, to take the water direct from the tributaries and prevent it from flowing over the swamp.

IMPROVING BROOKS.

Between the Mill Brook intake and the Farnham Dam, the brook has a fall of nearly 150 ft. in a distance of about 3 000 ft. Between the outlet of Roaring Brook diversion conduit and the flow line of the Farnham Reservoir, there is a fall of over 200 ft. in about 1 100. These brook channels have been improved and various small dams constructed across them for the purpose of aërating the water.

AVAILABLE SUPPLY OF THE COMPLETED SYSTEM.

The area tributary to the new Farnham Reservoir is estimated to be as follows:

Mill Brook, above the proposed reservoir....	0.38 sq. miles
Diverted from Monument Brook.....	0.20 sq. miles
Diverted from Roaring Brook.....	3.20 sq. miles
Total.....	3.78 sq. miles

This, added to the original collection area, less that portion of it now tributary to the Farnham reservoir, makes a total collection area of 10.21 sq. miles. The estimated available yield in a series of dry years, with the spillway of the Farnham dam at Elevation 1585, is 5 500 000 gal. per day.

In making the estimate of the available yield of the former and present collection systems in a series of dry years, the records of the Sudbury watershed from June, 1879, to December, 1883, inclusive, were used. Comparisons of the run-off from the Sudbury watershed with weir measurements in Roaring Brook and Mill Brook from September, 1907, to August, 1908, indicate that they are

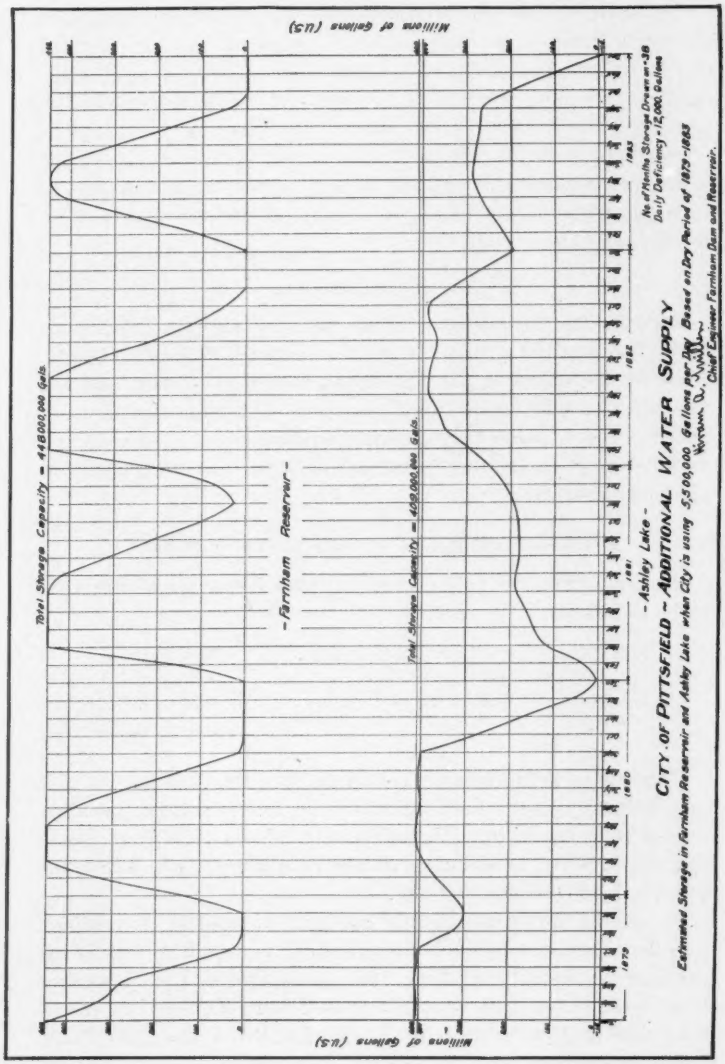

Millions of Gallons (U.S.)
Total Storage Capacity = 418,000,000 Gals.
- Farnham Reservoir -
Total Storage Capacity = 459,000,000 Gals.
- Ashley Lake -
1879
1880
1881
1882
1883
CITY OF PITTSFIELD - ADDITIONAL WATER SUPPLY
Estimated Storage in Farnham Reservoir and Ashley Lake when City is using 5,500,000 Gallons per Day. Based on Dry Period of 1879-1883
No of Months Storage Drawn on
Daily Deficiency - 12,000 Gallons
Chief Engineer Farnham Dam and Reservoir.

FIG. 9.

very nearly the same, although the yield from the Sudbury reservoir appears to be slightly larger.

ADDITIONAL MAINS.

In order to transmit, throughout the city, the increased quantity of water available by the addition to the water supply, without too great loss of pressure during fires, it was necessary to lay additional mains to and through the city.

The Ashley intake is lower than any of the other intakes, and is nearer to the city than any of them. It is necessary to have pipes of sufficient size for fire protection from this reservoir to the city only, as its storage of 23 000 000 gal. is more than sufficient to last through a fire. It is only necessary to have pipes of sufficient size from the Mill Brook intake, to the connection with the pipes from the Ashley intake, to provide for the maximum daily consumption of the city, less the least yield that can be expected in an extremely dry period from the other watersheds.

In planning the size of the pipes from the Ashley reservoir, it was deemed desirable not to consider the present 12-in. pipe from Ashley Lake to the distribution system, as it was laid with cement joints some forty years ago. A test, however, was made on a portion of two lengths of this pipe, without disturbing the cement joint connecting them. This pipe was subjected to a pressure of nearly 300 lb. per sq. in., and the joint as well as the pipe successfully stood the test. It was decided, therefore, not to abandon this pipe line at the present time, as on the outside it was practically as good as when laid and on the inside was only slightly tuberculated.

In estimating the size of the new pipe necessary to be laid from Ashley Lake to the distribution system it was assumed that the maximum rate of consumption, when the average was 5 500 000 gal. per day, would be 10 000 000 gal. per day; as, for instance, on a Monday morning; that it would be necessary to provide for the use of 4 000 gal. per minute for fire protection, or at the rate of 5 800 000 gal. per day, a total of 15 800 000 gal.; that the pressure at City Hall with this flow should not fall below 40 or 45 lb.; and that the distribution mains should be large enough to maintain good pressure throughout the city.

On this basis it was decided that it would be ultimately necessary to lay a 24-in. pipe from the Ashley intake to the distribution system, and a new 18-in. main from the Mill Brook intake to a connection with the new 24-in. pipe from Ashley intake. It was also decided that the present distribution system should be reinforced with a 20-in. main extending around the westerly side of the city; a 20-in. main extending around the easterly side of the city,

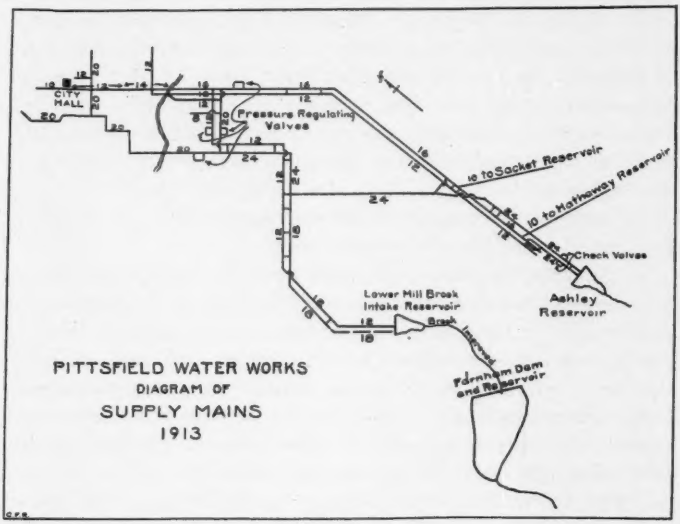


FIG. 10.

and a 20-in. main running north and south through the center of the city.

It was not deemed necessary, however, to do all the work at a time when the consumption of the city was less than 4 000 000 gal. per day. It was, therefore, decided to lay at the present time the main from Ashley intake to the distribution system, an 18-in. main for the greater portion of the distance from the 24-in. main from Ashley intake to the Mill Brook intake; a 20-in. distribution main through the center of the city; a 20-in. distribution main to the westerly side of the city, and leave the construction of the

remaining mains until such time as they should appear to be needed.

As the additional 18-in. pipe from the Mill Brook intake would cause pressures in the city so much higher than had been customary, and as the 12-in. pipe from Ashley intake to the city was so old, it was decided to introduce pressure reducing valves so that the extreme pressure at City Hall and on the 12-in. pipe would not exceed 75 to 80 lb.

If all the valves between the Mill Brook intake and the Ashley intake were left open, the Ashley intake reservoir might overflow; consequently check valves were placed on by-passes and positive gates opposite the check valve on the two mains near Ashley intake so that the flow into Ashley Lake could be regulated by the positive gates, and the check valves, opening toward the city, would open if the pressure dropped in case of fire.

The additional water supply for the city of Pittsfield was in charge of the committee on water supply of the city, consisting of Mr. W. H. Swift, chairman; Mr. James W. Hull, Mr. Arthur H. Rice, Mr. Edward A. Jones, and Mr. Daniel England. Mr. Hull, however, died before the actual work was well under way. Mr. A. B. Farnham, engineer of the board of public works, was principal assistant engineer, and Mr. John L. Howard was resident engineer of the Farnham Dam and Reservoir, and the writer was chief engineer on the Farnham Dam and Reservoir, and consulting engineer on the additional pipe lines.

TORRESDALE FILTER PLANT: METHODS AND RESULTS, 1907–1913.

BY FRANCIS D. WEST, CHEMIST IN CHARGE, TORRESDALE LABORATORY, AND JOSEPH S. V. SIDDONS, SUPERINTENDENT, TORRESDALE FILTERS.

[*Read September 10, 1913.*]

CONDITION OF DELAWARE RIVER AT TORRESDALE INTAKE.

The Delaware River rises in the southeastern part of the state of New York, about 190 miles above Philadelphia. The upper part of its watershed is mountainous and sparsely settled. The area of the watershed is about 8 600 sq. miles. The river is tidal to Trenton, about 18 miles above the Torresdale intake.

The principal affluent of the Delaware above Philadelphia is the Lehigh River, which flows through anthracite regions and reaches the Delaware at Easton, about 75 miles above the city. The principal cities and towns above Philadelphia are Easton, Bethlehem, and Allentown, on the Lehigh; Trenton on the Delaware; and the smaller places within a few miles of the Torresdale plant are Bristol, Burlington, and Riverside.

The Torresdale intake is about 12 miles above Chestnut Street Wharf. It is about 0.25 mile from the Pennypack Creek, which receives the sewage from Holmesburg, and the County Prison and House of Correction. The Pennypack Disposal Plant was built to take care of this sewage. The intake is about 3 miles above Frankford Creek, which is an open sewer and which drains a very thickly populated district. About eight sewers empty into the Delaware between Torresdale intake and Frankford Creek.

By far the worst pollution of the Delaware River comes from the city of Philadelphia, for every flood tide brings heavily polluted water up past the intake. This is especially the case when a heavy wind from the New Jersey shore prevents much mingling of the sewage with the purer water of the channel. To give some idea of what the conditions were before the Torresdale plant was started it is only necessary to state that the intake at Lardner's Point, which was then used, is only a half mile from

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Frankford Creek, with several large sewers discharging nearby, so dilute sewage was pumped on both tides. Bacillus coli communis is present in over 99 per cent. of the 1 c.c. tests and in about 90 per cent. of the tests of 0.1 c.c.

The range in bacteria in the Delaware River, together with that of the Filtered Water Basin for 1912, is given on Table 1. The range for turbidity for the same year is given on Table 2. Table 3 shows the turbidity for 1907 to 1912 inclusive; maximum, minimum, and average. Table 4 gives the corresponding bacteria. The results of chemical tests are given in Table 5.

TURBIDITY.

The normal turbidity of the Delaware River varies between 10 and 30, with an average of about 15 (between April and December). Occasionally, if winter sets in with heavy rains, the turbidity may reach 100 to 200, and the Torresdale plant will be overtaxed about the time of freezing temperature; ordinarily this is not the case and the river has a turbidity of 30 until the spring freshets, late in February. 1911 was an open winter and the turbidity was low all of the year. In 1912 the ground was frozen and covered with snow until February 22, when heavy rains brought down practically all of the winter's débris; the maximum turbidity, 1 050, was reached March 17. During the five years that the Torresdale plant has been in operation, the turbidity of the river has been 100 or over on 62 occasions, and between 50 and 100, 32 times, an average of 12 and 6 times a year respectively. In 1909 for nineteen days the turbidity was 100 or over. In 1911 a turbidity of 100 was not reached.

Compared with other rivers in the vicinity, the Delaware may be considered as having a remarkably low amount of dirt in suspension; although when we figure out how many pounds of dirt the Torresdale filters remove in a year, the figures are remarkable.

Taking the figure 36 parts per million as the average amount of dirt removed by the filters during 1912, for every million gallons of water there are 300 lb. of mud; filtering at a rate of 200 million gal. a day, about 60 000 lb. of mud per day, or 22 000 000 lb. per year, are removed. On March 17, the turbidity was 1 050, of which 1 000 parts were removed, or 1 660 000 lb. of mud in one

TABLE 1.

RANGE IN BACTERIA. 1912.

BACTERIA. Per C. C.	DELAWARE RIVER. Days.	EFFLUENT OF ROUGHING FILTERS. Days.	BACTERIA. Per C. C.	FILTERED WATER BASIN. Days.
0–100	0	..	0–5	86
101–200	0	..	6–10	101
201–300	0	1	11–25	107
301–400	0	3	26–50	34
401–500	0	6	51–100	15
501–750	1	19	101–200	12
751–1 000	6	55	201–500	4
1 001–1 500	16	44	501–1 000	5
1 501–2 000	36	42	1 001–2 100	2
2 001–2 500	27	31	Over 2 100	0
2 501–25 000	92	93	.....	..
5 001–10 000	86	36	.....	..
10 001–25 000	67	28	.....	..
25 001–50 000	22	6	.....	..
50 001–100 000	10	2	.....	..
Over 100 000	3	0	.....	..

TABLE 2.

RANGE IN TURBIDITY. 1912.

TURBIDITY. Parts per million.	DELAWARE RIVER. Days.	EFFLUENT OF ROUGHING FILTERS. Days.	TURBIDITY. Parts per million.	FILTERED WATER BASIN. Days.
0–10	154	297	0–1	339
11–25	146	41	2–10	18
26–50	38	8	11–25	7
51–100	9	6	25–51	2
101–250	9	6	Over 51	0
251–500	3	6	.....	..
501–750	4	2	.....	..
751–1 050	3	0	.....	..
Over 1 050	0	...	.....	..

TABLE 3.

TURBIDITY 1907–1912, INCLUSIVE.
Parts per million.

Year.	DELAWARE RIVER.			EFFLUENT OF ROUGHING FILTERS.			FILTERED WATER BASIN.		
	Max.	Min.	Average.	Max.	Min.	[Average.	Max.	Min.	Average.
1907*	190	5	32	...	..	..	10	0.5	2.8
1908	720	10	39	...	..	..	18	0	2.1
1909	350	7	37	260	1	12	24	0	.81
1910	60	6	25	130	0.5	8†	8	0	.22
1911	97	5	16	50	0.5	5†	3	0	.07
1912	1 050	2	37	610	0.5	18†	51	0	1.11

* Last six months.

TABLE 4.

BACTERIA PER CUBIC CENTIMETER (GELATINE 48 HRS. 19° CENT.).

Year.	DELAWARE RIVER.			EFFLUENT OF ROUGHING FILTERS.			FILTERED WATER BASIN.		
	Max.	Min.	Average.	Max.	Min.	Average.	Max.	Min.	Average.
1907*	270 000	600	17 000	.....	...	....	5 600	12	499
1908	60 000	550	6 600	.....	...	....	2 800	22	196
1909	120 000	400	9 100	31 000	100	3 400	2 000	7	103
1910	50 000	490	7 000	15 000	120	2 200	400	2	44
1911	61 000	700	7 600	30 000	250	2 600	480	2	25
1912	120 000	720	11 100	61 000	300	4 600	2 100	1	44

* Last six months.
Preliminary or roughing filters in service, January, 1909.

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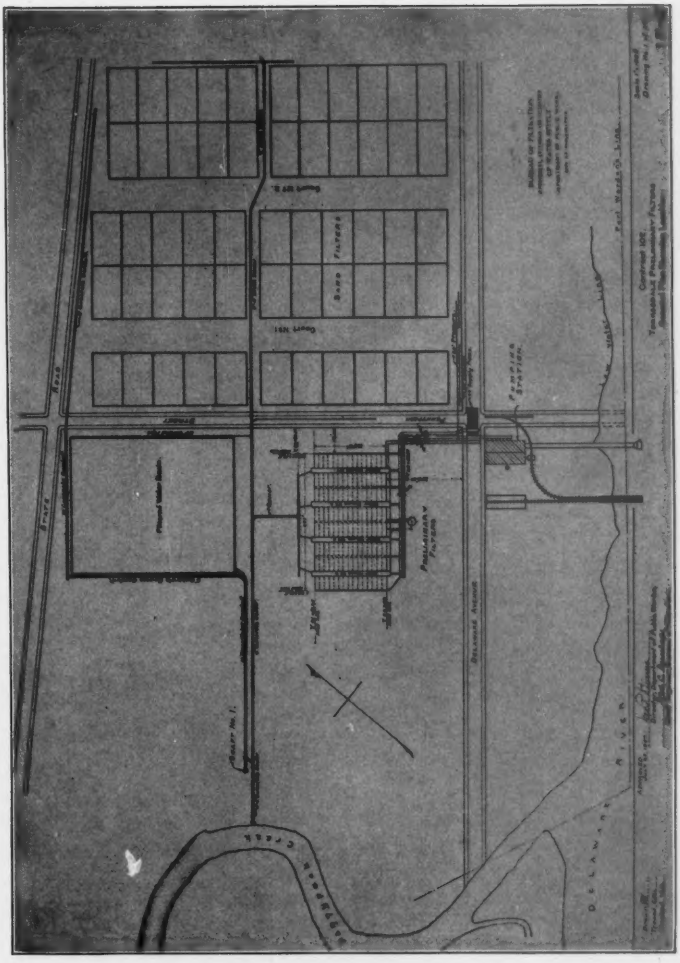

TABLE 5.

CHEMICAL TESTS FOR 1910, 1911, 1912.

Parts per million.

	1910.			1911.			1912.		
	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.	Min.
DELAWARE RIVER.									
Total solids	216	117	52	158	107	68	1 136*	103	72
Suspended matter	152	31	4	72	18.5	2	948*	25	1
Fixed susp.	....	.....	....	49	11.1	0	838*	18.5	0
Volatile susp.	....	....	....	23	7.5	2	110*	6.5	1
Turbidity	260	25	6	95	16	5	1 050	37	2
Total ammonia	1.24	.64	.44	.98	.54	.35	.68	.46	.22
Nitrites	.030	.009	.001	.028	.007	.001	.044	.013	.002
Nitrates	.76	.31	.08	.40	.18	.07	.56	.16	.06
Oxygen consumed	7.15	3.55	2.70	5.55	3.50	2.50	14.30*	3.22	2.15
Color	25	15+	10	25	20−	10	25	15+	10
Iron	8.68	2.22	.42	3.98	2.08	.68	30.72*	1.91	.84
Chlorine	10.0	5.3	1.8	7.2	4.5	2.9	8.6	4.4	1.4
Alkalinity	46	27	12	41	24	10	38	26	10
Hardness	62	47	26	69	44	24	59	44	28
Sulphates	16	11	5	19	13	8	17	12	8
FILTERED WATER BASIN.									
Total solids	120	75	36	102	77	44	106	73	52
Turbidity	8	.22	0	3	.07	0	51	1.11	0
Total ammonia	.46	.24	.11	.34	.22	.14	.44	.19	.09
Nitrates	.85	.44	.24	.52	.25	.08	.64	.23	.10
Nitrites	.005	.0005	.000	.002	.000	.000	.008	.0003	.000
Oxygen consumed	3.25	1.85	1.05	3.75	2.00	1.45	2.90	1.80	.80
Iron	.46	.135	.00	.42	.08	.00	1.18	.09	.00

* Not averaged.

day. During the two weeks previous about 6 million lb. or 3 000 tons of dirt were filtered out of the water.

BACTERIA.

The bacteria count of the Delaware River fluctuates greatly, depending on the tide, from a few hundred to several thousand. The count is lowest at low tide and increases with the incoming tide. (Tables 1 and 3.)

CHEMICAL TESTS.

Of the chemical tests, those of "Oxygen consumed" and "suspended matter" are the most interesting and valuable. The organic matter in the Delaware is relatively high; about two parts are in solution. The coefficient of fineness, the ratio of the weight of suspended matter to the turbidity, is slightly over unity and the ratio of fixed to volatile suspended matter is about two to one. The Delaware is relatively soft; the hardness ranging from 26 to 69 and the alkalinity from 12 to 46, averaging about 26 parts per million.

MICRO-ORGANISMS.

The operation of the Torresdale Filter Plant is seriously affected by micro-organisms, which usually occur in greatest numbers in spring and summer, when the turbidity is least. During May and June of 1913, when the turbidity of the river was about 12, and that applied to the final beds 3 or thereabouts, the final beds went out of service very rapidly. In addition to the micro-organisms themselves, the water contains considerable amorphous matter, which forms a hard paste on or near the surface of the filters.

The forms most commonly encountered are the diatoms and green algæ. Of the Diatomaceæ, the form most prevalent is the Synedra, followed by Cyclotella, Asterionella, Cymbella, Amphora, and Pleurosigma in the order named, although 90 per cent. are Synedra and Cyclotella. The diatoms are most plentiful in February and again in May, declining during the hot months, but always remaining present.

Of the Chlorophyceæ, Protococcus is the most numerous, then

Conferva, Scenedesmus, and Staurastrum. Protococcus makes up about 80 per cent. The algæ of the chlorophyll type start during May and follow the temperature curve, declining rapidly in November.

Generally speaking, the Delaware River is relatively clear and free from fine silt for the greater part of the year; the turbidity is largely organic, fairly coarse, and removed readily by roughing filters, but containing considerable fine amorphous material which chokes up slow sand filters. It contains, in summer, many micro-organisms which decrease the runs of filters. In late winter the turbidity averages over 100, and is composed largely of fine clay. The water is badly polluted, and B. coli are always present, necessitating disinfection after filtration.

CONDITION OF TORRESDALE FILTER PLANT AT TIME OF STARTING, JULY 4, 1907.

The main plant, or slow sand filters, is composed of 65 ¾-acre beds with terra-cotta underdrains and the usual gravel supporting from 26 in. to 36 in. of sand of .25 to .35 mm. effective size and about 2 per cent. coefficient of uniformity. The first 24 beds contained about 36 in. of sand, and the remainder about 26 in.

The Torresdale Filtration Plant was started July 4, 1907. About 25 beds were ready for service; some others contained gravel, and the remainder neither sand nor gravel. The pumps for washing sand had not been installed.

Due to the high typhoid rate in the district supplied with water from the Delaware River and to the fact that promises of starting had been made from time to time, it was considered advisable not to await the completion of the plant but to filter as much as possible, knowing that even unfiltered water from Torresdale intake was better than that at Lardner's Point. The outer intake was not ready, so Gate House No. 2 was used, taking water from a temporary channel about 200 ft. long.

At the start, 40 million gallons were filtered daily. The output was increased gradually as the filters received their quota of sand, 26 in. of sand being placed in the filters instead of 36 in., as had been intended originally.

By November 7, the plant was filtering 60 m.g.d.; by April 13,

TABLE 6.

Torresdale Filters. Yield from First Run, 1907–1908.

Month.	No. of Filters Started.	Million Gallons.					Days Run			Turbidity Applied Water.
		Yield.			Average per Acre.	Average Rate per Acre.	Max.	Min.	Average.	
		Max.	Min.	Average.						
1907										
July	29	60	18	38	51	1.7	71	11	30	15
August	1	30	30	30	40	2.6	16	16	16	18
September	9	46	24	36	48	2.3	27	17	21	29
October	9	51	21	37	49	1.6	37	19	30	31
November	5	39	34	35	47	3.4	29	20	14	45
December	2	53	50	31	68	1.9	36	36	36	44
Total	55									
Average	..	..	..	..	37	49	1.8	..	..	28	30
1908										
April	5	60	47	53	71	1.2	63	57	60	21
May	5	73	57	66	88	1.3	77	64	70	43
Total	10									
Average	..	..	..	..	59	79	1.2	..	..	65	32

Note.— Filters are .75 acre in area.

Note.— Rate is in terms of million gallons per acre per day. To get gallons per square foot per hour multiply by .96. To get inches vertical velocity per hour multiply by 1.53.

TABLE 7.

YIELD FROM TORRESDALE FILTERS DURING THE PERIOD WHEN THE BROOKLYN METHOD OF WASHING SAND WAS EMPLOYED.

Month.	No. of Filters Cleaned.	MILLION GALLONS.					DAYS RUN.			Turbidity Applied Water.
		YIELD.			Average per Acre.	Average Rate per Acre.	Max.	Min.	Average.	
		Max.	Min.	Average.						
1907										
July	14	44	16	26	35	2.7	21	8	13	15
August	48	67	14	25	33	3.0	49	6	11	18
September	65	30	11	18	24	2.4	30	6	10	29
October	75	36	7	20	27	2.0	26	7	14	31
November	96	45	7	16	21	1.5	27	6	14	45
December	95	33	8	17	23	1.5	25	6	15	44
1908										
January	104	44	9	20	27	1.7	26	7	16	54
February	92	61	4	16	21	1.5	42	6	14	100
March	20	45	5	19	25	1.4	31	8	18	48
Total	609									
Average		..	..	19	25	1.8	..	..	14	42

The first runs during 1907, with an average turbidity of 30, yielded an average of 49 million gal. per acre per run at a rate of 1.8 million gal. per acre day.

The ten filters started in 1908, with the same turbidity, yielded an average of 59 million gal. per run, or 79 million per run per acre, operated at a somewhat lower rate — 1.2 million gal per acre day.

The Brooklyn method yielded an average per run of but 25 million gal. per acre, averaging but fourteen days of service, with actual yields of as low as 4 million gal. The turbidity at this time averaged 42.

TABLE 8.

YIELD DURING PERIOD WHEN METHOD OF SCRAPING AND PILING WAS USED FOR WASHING SAND.

Month.	No. of Filters.	Million Gallons.					Days Run.		
		Yield.			Average per Acre.	Average Rate per Acre.	Max.	Min.	Average.
		Max.	Min.	Average.					
1908									
March	32	56	25	38	51	1.7	38	22	30
April	39	54	21	33	44	2.0	39	14	22
May	45	69	20	35	47	2.0	42	12	23
June	47	66	22	35	47	2.6	32	12	18
July	57	59	27	35	47	2.7	28	13	17
August	71	48	23	33	44	2.4	27	15	18
September	78	51	17	31	41	2.6	26	11	16
October	66	54	19	34	45	2.7	31	10	17
November	61	52	24	36	48	2.8	26	11	17
December	34	54	24	41	55	2.8	30	14	20
Total	530								
Average	..	..	..	..	35	47	2.4	..	..	19
1909									
January	17	142	25	68	91	2.8	57	12	32
July	2	64	44	54	72	4.8	26	15	15

October	1	..	..	68	91	5.1	..	..	18
November	22	81	19	41	55	4.2	20	6	13
December	35	48	12	29	39	4.3	16	4	9
Total	77								
Average	..	..	..	43	57	3.6	..	..	16
1911									
June	3	72	38	56	75	5.4	19	10	14
1912									
March	42	70	3	35	47	4.7	17	2	10

During 1908 the scraping and piling method yielded almost the same amount as the ejection method, an average of 35 million, compared with 39 million gal. per run.

During 1909 it was used at a different season of the year, and it was not used at all in 1910.

During March, 1912, it was used successfully to get a bed back into service quickly, raking being of no value, due to the deep penetration, and it was necessary to keep the filters working.

Although by April, 1912, the average turbidity had dropped to 12, and by May to 2, the filters were still in such a condition that in May 65 filters were spaded, getting a maximum run of 229 million and a minimum of 11 million, with an average of 51 at a 4.5 million rate.

From March 1 to May 15, it was necessary to work twenty-two hours a day, due to the deep penetration caused by the high turbidity of February and March.

1908, the quantity was 86 m.g.d., and by May 12, 110 m.g.d., the maximum without pre-filters. The maximum rate was 3 million gallons per acre daily. Table 6 shows the yield from the filters from the first run, 1907–1908.

BROOKLYN METHOD.

As has been stated, the wash pumps were not ready and so it was necessary to resort to other means of washing sand. The Brooklyn method was used.

This method originated in the Department of Water, Gas, and Electricity of the City of New York, and had been used successfully at Jerome Park and Hempsted. It obviates the removal of sand from the filter.

"The water is drained to a depth of a few inches above the sand surface and the outlets, which permit the water remaining above the surface of the sand to flow off, are opened. The wash water is applied at one end of the bed and flows over the sand with a velocity of about 0.5 ft. per sec. The direction is guided by boards set on edge, thus forming channels of the width of a bay, or 15 ft. As the water flows over the sand the layer is raked by men standing on the surface until the water runs practically clear, when the water is applied through the usual inlets and filtration resumed."

This method was used until March, 1908. It was not a success, due to the peculiar quality of the sediment; the combination of amorphous organic material, clay, and micro-organisms formed a hard pasty-like layer extending down for a depth of about 4 in. and of such a consistency that it was possible to hold a large cake of it on the hand without its breaking apart.

As would be expected with green filters, the efficiency during 1907 was not high. The runs were short, and after the output had reached 100 million gal. it was necessary to resort to extreme measures to get water through the filters.

Quantity became all-important; quality was a decidedly second consideration. To assist in getting water through the filters the method of spading was used. This consisted of going over the surface of the filter with a garden spade, thrusting it down to a depth of about 8 in., and working it back and forth to break up the pasty layer.

EJECTOR IN COURT, RESTORING SAND.

Needless to state, this caused a further drop in efficiency with but little assistance in length of runs. Runs became as short as 4 million gal.

Table 7 shows the yield during the period when the Brooklyn method was employed for washing sand.

The Brooklyn method was finally abandoned, and the upper end of the dirty sand was scraped into piles. The filter was then put back into service in the usual manner. This method reduces the effective size by about 15 per cent. It originated at Torresdale and was born of necessity. It is a convenient way to get a filter back into service quickly. The effluent compares favorably with that from any other method.

Table 8 shows the yield of the filters at this time.

As soon as the pumps had been installed, the regulation ejection method for washing sand was used, the sand being scraped into piles, placed in the ejectors, and carried out with the dirt into the court by a force of water under a pressure of 85 lb. per sq. in.

It was necessary to pare off about 8 in. to get down to clean sand.

Table 9 shows the yield of the filters while this method was in use.

PRELIMINARY FILTERS.

These filters are of the mechanical type without coagulant. They are arranged in batteries of 15 beds, with two batteries facing each filter house, of which there are four; making 120 beds. Each bed measures 20 ft. 3 in. by 60 ft. and is controlled by an individual operating table. The influent is through a 16 in. hydraulic valve in the rear. The filtering material consists of 15 in. of gravel, 2 in. to 3 in.; 4 in. of gravel, $\frac{5}{8}$ in. to $1\frac{1}{2}$ in.; 3 in. of gravel, $\frac{1}{4}$ in. to $1\frac{1}{2}$ in.; and 8 in., $\frac{1}{8}$ in. to $\frac{1}{4}$ in., a total of 30 in. and 12 in. of sand, with effective size .8–1.0 mm.

The depth of water over the bed is 4 ft. They are washed by reverse flow of water with air.

The period of washing is, air, three minutes; water, one minute; air, two minutes, and water, $1\frac{1}{2}$ minutes, when the filters are filled and put into service. Washing without air was tried, but it was found that the wash water passed through channels and a thorough wash was not obtained.

TABLE 9.

YIELD FROM FILTERS DURING PERIOD WHEN EJECTION METHOD WAS USED FOR CLEANING SAND.

Month.	No. of Filters Removed.	Million Gallons.					Days Run.			Turbidity Applied Water.	Average Cubic Yards Sand Removed.
		Yield.			Average per Acre.	Average Rate per Acre.	Max.	Min.	Average.		
		Max.	Min.	Average.							
1908											
March	9	61	43	50	67	2.1	40	25	32	44	261
April	28	52	25	39	52	2.3	39	18	24	21	269
May	29	80	26	42	56	2.5	45	14	22	43	261
June	49	80	23	38	51	2.7	34	14	19	30	187
July	37	69	23	38	51	2.5	32	12	20	26	152
August	25	56	21	38	51	2.7	31	13	19	28	211
September	28	42	19	33	44	2.8	23	10	16	29	223
October	30	49	24	37	49	2.7	24	11	18	30	275
November	29	64	23	42	56	2.8	29	11	20	35	296
December	18	75	29	45	60	2.6	34	12	23	39	374
Total	282										
Average	..	..	..	..	39	52	2.6	..	..	20	32	239
1909											
January	13	261	80	168	224	3.6	79	35	63	29	417
February	21	373	168	235	313	4.3	105	57	72	24	344
March	12	379	121	260	347	4.3	104	52	80	8.3	277
December	16	199	37	108	144	5.1	50	11	28	56	433

Total	62										
Average	..	..	..	193	257	4.3	..	..	60	29	375
1910											
January	54	191	43	97	129	4.4	53	18	29	17	355
February	14	249	60	174	232	4.7	65	18	49	17	305
March	3	292	144	232	309	4.0	91	50	77	16	422
Total	71										
Average	..	..	..	118	157	4.4	..	..	35	17	348
1911											
April	2	125	97	111	148	3.5	45	40	42	7	342
June	16	195	50	78	104	4.0	63	19	26	5	112
July	2	83	72	77	103	4.5	24	21	23	1	145
Total	20										
Average	..	..	..	81	108	4.1	..	..	27	4	133
1912											
March	82	187	10	64	85	5.0	55	4	17	95	324

In 1908, without pre-filters, with a turbidity of 32, the average yield was 39 million gal.; in 1909, with pre-filtered water and deep cleanings, the average yield was 193 million, with about the same turbidity.

In 1910, under somewhat better conditions as regards turbidity, the average yield was 118 million gal.

In the summer of 1911, with a turbidity of but 4, the average yield was only 81 million gal., showing the effect of micro-organisms.

In 1912, at the time of the record turbidity, we had one run of but 4 million gal. and another one of 187 million.

The pre-filters have removed over 60 per cent. of the dirt; have made it possible to double the output of the plant, giving 210 million instead of 110 million gal. per day; have enabled the final beds to be operated at a maximum of 6 instead of 3 million gal. per acre per day; have more than doubled the lengths of runs of the final beds, as well as the quantity filtered per run, as will be seen by tables; and have made a marked reduction in the cost per million gallons filtered.

REMOVAL OF SUSPENDED MATTER.

The principal usefulness of a roughing filter is to remove the turbidity or suspended material. The average by months for the past four years is shown in Table 10, and Fig. 1.

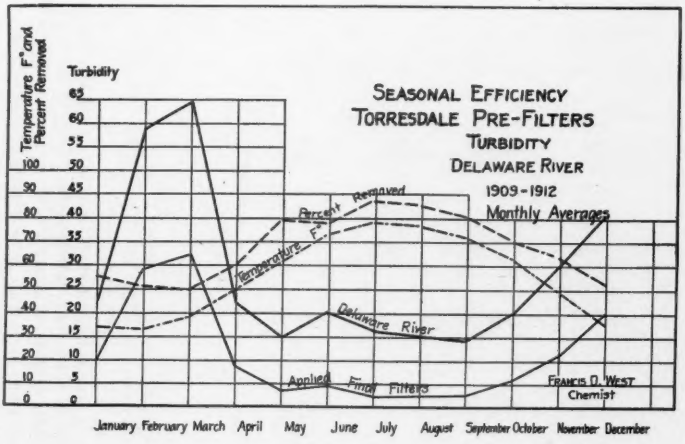

FIG. 1.

It will be seen from Fig. 1 that the amount of turbidity is highest in February and March, with a secondary rise in December; also that the amount between April and October averages about 15 parts per million.

The efficiency seems to vary as the temperature, although this may be due to the fact that the turbidity in summer is low; how-

TABLE 10.

TURBIDITY. TABLE SHOWING SEASONABLE EFFICIENCY OF PRE-FILTERS AT TORRESDALE, 1909–1912, INCLUSIVE.

Month.	1908.	1909.			1910.			1911.			1912.			Average, 1909–1912, inclusive.		
	River.	River.	Applied.	Per Cent. Removed.	River.	Applied.	Per Cent. Removed.	River.	Applied.	Per Cent. Removed.	River.	Applied.	Per Cent. Removed.	River.	Applied.	Per Cent. Removed.
January.....	54	40	29*	..	36	17	53	24	9.8	59	8.0	3.2	60	23	10	56
February....	100	60	24	60	50	17	66	24	9.5	60	109	64	41	61	29	52
March.....	48	25	8.3	67	30	16	48	15	8.5	43	179	95	41	62	32	49
April.....	21	20	6.1	59	26	9.3	64	16	7.1	56	25	12	52	22	8.7	60
May.....	36	24	5.6	77	17	3.5	79	9.0	2.0	78	10	2.4	76	15	3.4	79
June.....	30	23	2.6	89	24	6.7	72	20	5.4	73	12	2.8	77	20	4.4	78
July	26	27	4.5	83	15	2.0	87	11	1.2	89	10	.8	92	16	2.1	87
August.....	28	25	4.7	81	14	1.9	86	12	1.5	88	9.5	1.2	87	15	2.3	85
September...	29	21	4.1	80	14	2.0	86	13	3.6	72	9.5	1.3	86	14	2.8	80
October.....	30	31	10	68	18	2.3	87	10	3.4	64	22	8.0	64	20	5.9	70
November...	35	33	14	58	37	13	65	18	6.6	63	30	12	60	30	11	63
December...	40	108	56	48	28	10	64	14	5.5	61	18	8.0	56	41	20	52
Average.....	39	37	12*	68	25	8*	67	16	5*	67	38	18*	52	29	11	62

* Omitted from calculations. In operation only a few days.

TABLE 11.

TABLE OF MONTHLY BACTERIAL EFFICIENCY OF PRE-FILTERS AND FILTER NO. 1 FOR YEAR 1911. (BACTERIA PER C. C.)

Month.	River.	Applied Final Filters.		Effluent Final Filter No. 1.	
			Per Cent. Removed.		Per Cent. Removed.
January	4 450	2 430	45.2	28	98.8
February	6 200	2 320	62.6	64	97.2
March	4 320	1 610	62.7	16	99.0
April	3 390	1 490	54.6	15	99.0
May	8 050	2 580	68.0	13	99.5
June	8 370	2 920	65.1	13	99.6
July	8 500	2 460	71.2	8	99.7
August	10 800	2 700	73.2	8	99.7
September	8 950	3 380	62.2	8	99.8
October	4 500	1 980	56.0	6	99.7
November	12 900	4 880	62.1	48	99.0
December	8 450	3 110	63.2	38	98.8
Average	7 410	2 550	65.6	22	99.1

ever, the turbidity does rise occasionally in May, when the efficiency of the pre-filters is high; both the pre- and final filters appear to experience no difficulty in handling a comparatively high turbidity if it comes after the last of April. It will be seen that the efficiency is but 50 per cent. in March and nearly ninety in July.

REMOVAL OF BACTERIA.

This is of secondary importance, but the pre-filters have averaged for the four years as follows: 1909, 62.6 per cent.; 1910, 68.1 per cent.; 1911, 65.5 per cent.; 1912, 60.4 per cent. The efficiency varies from sample to sample without any apparent consistency; there is an apparent removal of 90 per cent. one day, and 60 per cent. the next.

Table 11 gives the bacterial efficiency for 1911 and shows the number of bacteria in the river, in the effluent of the pre-filters, and in that of a typical slow sand filter for a normal year, 1911.

As a rule, when the turbidity efficiency drops, with high turbidity, the bacterial efficiency drops as well, though not so markedly.

Generally speaking, the pre-filters remove about 65 per cent. of the bacteria.

The efficiency in removing micro-organisms is about 60 per cent. but it is thought that they grow on the final filters in spite of the fact that the covers are kept closed.

The following table shows the lengths of runs of pre-filters:

Year.	Total Washing.	No. per Filter.	Per Cent. Wash Water.	Average Days Run per Filter.	Turbidity.
1909	12 648	105	.5	3.4	37
1910	40 119	334	1.0	1.1	25
1911	22 763	190	.6	1.9	16*
1912	19 130	159	.7	2.3	37

* Washed at 3-ft. loss of head.

After continuous use for four years the amount of sand has been reduced by about 2 in., due to loss in washing and to the fact that some has fallen through to the gravel; the finest gravel and some

TABLE 12.

YIELD FROM FILTERS DURING PERIOD WHEN NICHOLS METHOD OF CLEANING SAND WAS USED.

Month.	No. of Filters Cleaned.	MILLION GALLONS.					DAYS RUN.			Turbidity.	Cubic Yards Sand Cleaned.
		YIELD.			Average per Acre.	Average Rate per Acre.	Max.	Min.	Average.		
		Max.	Min.	Average.							
1909											
January.....	6	281	104	208	277	4.1	97	50	68	29	418
February....	6	519	272	340	453	5.0	122	55	90	24	374
March.....	7	366	256	319	425	4.9	99	69	86	8.3	267
April.....	8	309	212	261	348	5.3	81	54	66	6.1	196
May.....	14	195	71	127	169	3.9	52	32	43	5.6	215
June.....	19	153	60	102	136	4.9	39	19	28	2.6	207
July.....	31	171	53	95	127	5.1	43	16	25	4.5	216
August.....	25	110	62	87	116	4.8	29	19	24	4.7	147
September...	22	137	59	95	127	5.1	34	20	25	4.1	120
October.....	23	142	73	101	135	5.2	35	23	26	10.0	170
November...	32	122	63	96	128	5.1	32	17	25	13.5	236
December...	36	235	51	120	160	5.0	62	18	32	56.0	359
Total.....	229										
Average...	...	...	...	...	123	164	4.5	...	...	34	...	229

1910											
January.....	0	...	...	...	...	...	...	..	..	17	...
February....	20	569	215	340	453	5.0	148	68	91	17	486
March.....	17	376	289	329	439	4.4	115	91	99	16	740
April.....	13	293	133	225	300	4.5	86	47	66	9.3	923
May.....	9	222	142	185	247	4.4	72	42	56	3.5	896
June.....	11	244	74	144	192	4.5	73	22	42	6.7	726
July.....	28	283	92	193	257	4.6	76	25	56	2.0	527
August.....	27	241	122	178	237	4.0	64	53	60	1.9	368
September...	9	164	68	114	152	3.7	61	27	41	2.0	391
October.....	29	132	75	102	136	4.0	43	29	34	2.3	267
November...	33	226	93	148	197	4.7	64	29	42	12.7	268
December...	36	278	112	210	280	4.9	76	31	59	10.5	388
Total.....	232										
Average...	...	...	...	195	260	4.5	...	..	58	..	470

TABLE 12.—*Continued.*

YIELD FROM FILTERS DURING PERIOD WHEN NICHOLS METHOD OF CLEANING SAND WAS USED.

Month.	No. of Filters Cleaned.	Million Gallons.					Days Run.			Turbidity.	Cubic Yards Sand Cleaned.
		Yield.			Average per Acre.	Average Rate per Acre.	Max.	Min.	Average.		
		Max.	Min.	Average.							
1911											
January	23	292	189	251	335	4.9	72	63	69	9.8	475
February	13	359	203	268	357	4.8	99	58	74	9.5	1 230
March	18	401	160	293	391	4.8	102	50	82	8.5	796
April	19	249	112	177	236	4.5	67	48	53	7.1	583
May	7	174	57	104	139	3.5	59	27	40	2.0	842
June	22	156	76	110	147	4.6	48	23	32	5.4	436
July	35	170	65	114	152	3.8	49	27	40	1.2	265
August	17	156	49	116	155	3.7	46	20	42	1.5	444
September	28	203	82	125	167	4.2	75	27	40	3.6	332
October	27	149	58	112	149	3.6	57	27	41	3.4	318
November	30	346	95	159	212	3.9	97	37	54	6.6	320
December	26	233	83	160	213	4.3	70	32	50	5.5	333
Total	265										
Average	...	...	...	...	160	213	4.3	...	..	50	...	452

1912											
January.....	31	235	59	138	184	4.8	58	21	38	3.2	266
February....	21	117	30	60	80	3.8	36	11	21	64.0	283
March.....	11	289	134	182	243	4.7	80	34	49	72.0	1 010
April.....	30	262	120	149	199	3.5	74	39	56	12.0	1 093
May.....	22	179	73	119	159	3.8	62	28	42	2.4	1 130
June.....	23	195	83	139	185	4.1	60	30	45	2.8	418
July.....	26	206	78	151	201	4.2	63	24	48	.8	285
August.....	22	202	71	154	205	4.1	73	25	50	1.2	249
September...	25	112	70	91	121	3.5	44	30	35	1.3	198
October.....	33	124	54	88	117	3.5	49	21	33	8.0	284
November...	27	146	90	117	156	3.8	48	32	41	11.7	319
December...	32	207	93	137	183	3.8	71	31	49	8.0	301
Total.....	303										
Average...	...	...	...	126	168	4.3	...	..	39	...	466

On examining the table of Nichols method, it will be seen that the filters cleaned during February, March, and April have the longest runs, the lengths of the runs decreasing until about June and then averaging about the same for the rest of the year.

It will also be noticed that the runs are longer than those obtained from any other method. The average yields for the four years being, 1909, 123; 1910, 195; 1911, 160; and 1912, 126 million gal.

The longest run in the history of the plant, 148 days, was from a filter cleaned by this method, the quantity being 569 million gal. The second longest run, of 122 days for 519 gal., occurred after a cleaning in February, 1909.

One inch depth corresponds to 100 cu. yd. of sand cleaned, so the figures in cubic yard will give the average depths of cleaning by this and the ejection method.

After the freshet of 1912, it was necessary to clean for a depth of 10 in. during March, April, and May, showing the deep penetration.

We are about to start one filter with the Brooklyn method, to see how this method will work with pre-filtered water; but from the deep penetration shown by the above tables it is thought that we will experience the same difficulty as before, the runs becoming gradually shorter the longer the method is used.

of the next grade are mixed with the sand. In a couple of years at most the material will have to be regraded; except for this, the plant is operating as effectively as it did at the start.

There is no question that if we had about 24 in. of sand instead of 12 in. the efficiency would be greater in winter.

The maximum output of the plant was 240 million gal.; the average has been about 200 million since the starting of the pre-filters.

METHODS OF CLEANING FINAL FILTERS.

Almost coincident with the start of the pre-filters was the introduction of the Nichols machine. This, together with raking as an auxiliary, has practically superseded all others at Torresdale.

NICHOLS METHOD.

Mr. E. M. Nichols, after experimenting for about three months at Torresdale, designed a machine which enables the operator to wash the sand on the filter without ejecting, thereby saving about 25 cents per cu. yd. It has the further advantage that the thickness of the filter is not reduced and the danger of breaking through is greatly lessened; moreover, the filter can have the rate changed with less danger of reducing the efficiency.

The machine consists of an inverted cylinder inside a closed jacket. The dirty sand is fed into ejectors in the usual manner, and the wash water with the sand and dirt instead of going out to the court passes through the machine. The water strikes the side of the cylinder and the sand, being heavy, drops to the bottom and is allowed to pass through a nozzle and spread on the filter It has a turbidity of about 150 to 200, i. e., 100 gm. of sand in 1 000 c. c. of water. It uses but 1 200 gal. per cu. yd. instead of 2 800 used by ejection method.

About 2 per cent. of the fine sand goes out with the water and dirt to the court where it settles, the water and dirt going to the sewer.

The depth cleaned at one time by this machine depends upon the penetration and may vary from a couple of inches to 8 or 10 in.

Sometimes a preliminary cleaning will be given if the filter is needed when the upper inch or so is removed, reserving a deeper cleaning for a later date when the pressure for water has been relieved.

FIG. 1.
CLEANING BY NICHOLS MACHINE.

FIG. 2.
RESTORING SAND BY NICHOLS MACHINE. MACHINE IN FILTER.

Table 12 gives the yield of the filters while the Nichols method has been in use.

RAKING.

This is going over the filter with rakes and breaking up the *schmutzdecke*, enabling the operator to get several million gallons at a very low cost. We rake once and sometimes twice between washings.

In 1912, at the time of the flood, practically every method except the Brooklyn was used to get the water through, and if it had not been for the hypochlorite, the water would have had a very high count and contained pathogens.

Table 13 gives the yield of the filters while the raking method was used.

Table 14 gives a summary of the results from the different methods of cleaning sand.

LOSS OF HEAD IN SPRING.

There is one period of the year when we have what we call a loss of head; this may last for a couple of weeks or only for one or two days.

It usually follows the spring freshets when the water has become normal and the turbidity low. The filters instead of increasing in resistance decrease, and the head drops. There appears to be something that destroys the *schmutzdecke* at this time faster than it forms. On a couple of pans that we had placed in one of the filters previously we found from 200 to 300 snails. These may or may not have had something to do with the loss of head. The bacterial efficiency at this time remained high.

GENERAL EFFICIENCY OF PLANT.

The average bacterial efficiency has been as follows:

1907	97.65 per cent.
1908	97.05 per cent.
1909	99.01 per cent.
1910	99.36 per cent.
1911	99.67 per cent.
1912	99.60 per cent.

We have on many occasions had counts of 0 per c.c. (on gelatine) in not only the filtered water basin but the effluent of filters.

TABLE 13.

YIELD FROM FILTERS DURING PERIOD WHEN METHOD OF RAKING HAS BEEN EMPLOYED.

Month.	First Rake.			Second Rake.			Third Rake.		
	No. Filters.	Yield.*	Days Run.	No. Filters.	Yield.	Days Run.	No. Filters.	Yield.	Days Run.
1909									
January....	32	67	33	4	48	20	..	..	..
February...	7	128	40	1	55	27	..	..	..
March.....	6	117	41	..	..	..	..	..	..
April.....	19	144	45	2	89	29	..	..	..
May.....	12	132	38	2	93	38	1	23	12
June.....	26	67	17	23	48	13	5	41	12
July.....	33	94	24	18	70	19	6	47	14
August....	23	92	24	27	75	20	1	52	13
September..	23	97	25	18	67	19	12	55	17
October....	26	65	18	29	47	14	22	41	14
November..	20	43	13	25	34	12	21	31	10
December..	33	31	10	2	35	13	..	..	..
Total....	260			151			68		
Average..	...	80	20	...	56	17	..	40	13

1910									
January....	13	42	14	...	..	..	..	..	..
February...	29	73	22	1	93	28	..	..	..
March.....	7	84	29	3	65	22	..	..	..
April.....	19	122	37	13	43	16	..	..	..
May.....	...	...	..	...	...	..	1	47	23
June.....	34	67	19	17	43	14	2	29	12
July.....	25	122	33	32	57	16	1	36	11
August.....	6	183	49	10	82	20	..	..	..
September..	17	94	25	7	67	18	..	..	..
October....	32	91	25	7	53	16	..	..	..
November..	28	71	21	8	35	12	..	..	..
December..	26	54	17	9	28	10	..	..	..
Total....	236			107			4		
Average..	...	84	26	...	52	17	..	35	14

*To get yield per acre per run, multiply by $\frac{1}{3}$.

TABLE 13. — *Continued.*

Month.	First Rake.			Second Rake.			Third Rake.		
	No. Filters.	Yield.	Days Run.	No. Filters.	Yield.	Days Run.	No. Filters.	Yield.	Days Run.
1911									
January....	14	76	26	..	..	..	..	..	..
February...	17	80	26	1	44	19	..	..	..
March.....	23	93	31	11	35	13	..	..	..
April.....	9	172	44	11	44	23	..	..	..
May.....	8	113	33	4	111	28	..	..	..
June.....	39	63	17	15	37	12	..	..	..
July.....	37	111	22	8	58	15	..	..	..
August....	22	107	26	13	67	16	..	..	..
September..	18	113	28	9	69	16	1	53	19
October....	27	114	23	5	65	18	..	..	..
November..	31	95	24	2	44	13	..	..	..
December..	14	82	22	1	62	22	..	..	..
Total....	259			84			1		
Average..	...	98	26	..	49	14		53	19

1912				*First*	*Raking*				
January....	31	130	24	67	89	5.2	30	8	17
February...	21	97	3	59	79	5.3	22	2	15
March.....	..	..	..	..	..	..	..	..	..
April.....	2	75	68	71	95	4.7	20	20	20
May.....	11	162	98	133	177	5.2	40	29	24
June.....	46	182	33	96	128	5.1	48	8	25
July.....	11	172	78	96	128	5.3	50	19	24
August.....	22	157	74	110	147	5.1	38	20	29
September..	30	117	62	88	117	5.1	31	17	23
October....	30	104	41	75	100	5.0	34	12	20
November..	26	119	40	77	103	4.7	30	10	22
December..	27	79	27	57	78	4.3	25	12	18
Total....	257								
Average..	..	..	..	83	111	5.0	..	..	22

TABLE 13. — *Concluded.*

Month.	No. Filters Raked.	Million Gallons.					Days Run.		
		Yield.			Average per Acre.	Average Rate per Acre.			
		Max.	Min.	Average.			Max.	Min.	Average.
1912				*Second*	*Raking*				
January....	1	17	17	17	23	3.8	6	6	6
February...	..	..	..	..	..	..	..	..	..
March.....	..	..	..	..	..	..	..	..	..
April.....	..	..	..	..	..	..	..	..	..
May.....	..	..	..	..	..	..	..	..	..
June.....	6	72	33	53	71	4.7	20	9	15
July.....	15	58	35	50	67	4.2	17	10	16
August.....	5	76	42	64	85	4.7	21	12	18
September..	9	79	35	56	75	5.0	24	8	15
October....	10	71	32	48	64	4.6	24	19	14
November..	13	49	18	31	41	3.7	15	7	11
December..	7	39	16	27	36	3.6	15	7	10
Total....	66								
Average..	..	..	..	45	60	4.3	..	..	14

TABLE 14.

SUMMARY OF DIFFERENT METHODS OF CLEANING.

No. of Filters Cleaned.	Million Gallons. Yield. Max.	Yield. Min.	Yield. Average.	Average per Acre.	Average Rate per Acre.	Days Run. Max.	Days Run. Min.	Days Run. Average.
			Method First Runs.					
65	73	21	40	53	1.6	77	11	34
			Brooklyn.					
609	67	4	19	25	1.8	49	6	14
			Scraping and Piling.					
530	69	17	35	47	2.4	39	10	19 Before pre-f.
122	142	3	40	53	4.0	57	2	14 After pre-f.
			Ejection Method.					
282	80	19	39	52	2.6	45	10	20 Before pre-f.
235	379	10	116	155	4.5	105	4	34 After pre-f.
			Rakings.					
1 012	182	3	85	113	5.0	50	2	24 1st rake.
408	79	16	50	67	4.3	24	7	16 2d rake.
62		39	52					13 3d rake.
			Nichols Method.					
1 029	569	49	141	188	4.4	148	11	42
			General Averages.					
1 486	80	4	30	40	2.1	77	6	18 Before pre-f.
2 958	569	3	96	128	4.4	148	2	29 After pre-f.

NOTE. — Data for Max., Min., and Rate for Rakings for 1909, 1910, and 1911 not given.
Method of spading for 1912 omitted from averages.

The average count for the basin under normal conditions is below 10.

The water is clear with a turbidity of 0 for about forty-eight weeks of the year.

We are putting out enough water to supply London: are operating our slow sand filters at twice the standard rate: we have no sedimentation basin but must take the water in large doses just as we find it, and we have an effluent which compares favorably with that of any plant in existence.

HYPOCHLORITE.

Bleach was first used at Torresdale in the form of hypochlorite of soda produced electrolytically, during September, 1909. Two cells manufactured by the National Laundry Company were used. A current of 35 amperes at 110 volts was used to decompose a brine solution. The temperature of the bleach solution averaged 110 degrees fahr. The chlorine and the soda were allowed to recombine and the temperature was so high that chlorates were formed.

The bleach was applied directly in front of the inlet valve of one of the pre-filters operated at a 20 million gal. rate, or ¼ normal. The conclusions were, in part, that the bacterial efficiency of the filter was considerably less than that of filters operated at four times the rate without treatment.

Hypochlorite was again used in December, 1910. Due to the fact that the bacterial efficiency of slow sand filters decreases materially in cold weather, and the fecal organism, B. coli communis, was present in the filtered water, it was decided to use chloride of lime to disinfect the water in the filtered water basin.

The plant consisted of two cedar mixing tanks, 5 ft. in diameter and 4 ft. deep, and one solution tank of the same dimensions, and a yellow pine orifice tank, cubical in shape, 2 ft. on a side.

The cedar tanks were perforated by the bleach and were later lined with cement, decreasing the capacity from 500 to 380 gal. A concrete orifice tank was substituted for the wooden one. Mixing is done by hand, by two laborers using paddles, the period of agitation being about an hour. Analyses are made of the solution in the tanks, of the powder, and of the sludge.

At the start 540 lb. of powder were used for 200 million gal. of water. The treatment was continued for the first four months of 1911, when it was stopped until December.

During the five months of 1911, when bleach was used, the number of positive tests for B. coli in the filtered water was as follows:

1911.

	Filtered Water Basin.		Tap at Lardner's Point.	
	Per Cent. + 1 C. C.	Per Cent. + 10 C. C.	Per Cent. + 1 C. C.	Per Cent. + 10 C. C.
January, April, and December	4.0	13.3	2.4	12.9 treated
May to November inclusive ..	14.5	58.0	10.0	48.6 untreated

May to November the efficiency of the filter plant is at its highest and the bacteria count low, averaging less than 20 per c.c.

During 1912 and 1913 the treatment has been continuous and the figures are:

1912.

Filtered Water Basin.					Tap at Lardner's Point.				
No. Tests.	1 C. C. +	Per Cent. +	10 C. C. +	Per Cent. +	No. Tests.	1 C. C. +	Per Cent. +	10 C. C. +	Per Cent. +
364	15	4.1	80	22.0	302	6	2.0	51	16.9

This shows a considerable reduction over 1911, but the results are still too high.

During 1912, when ½ part or more was used, the figures were: Filtered Water Basin, 1 c. c.+, 2.5 per cent.; 10 c. c. +, 14.9 per cent. Lardner's Point, 1 c. c. +, 1.1 per cent.; 10 c. c. +, 9.1 per cent.

For the first seven months of 1913, during which over ½ part has been used continuously, the following figures have been obtained.

For the Filtered Water Basin, out of 212 tests of 1 c. c. but two were positive, or 0.9 per cent.; for 10 c. c., 7 were positive, or 3.3 per cent.; and for Lardner's Point the percentages are .6 per cent. and 6.2 per cent.

This is a reduction from 1910 for 1 c. c. of 12.7 per cent. to .9 per cent., and for 10 c. c., 38.8 per cent. to 3.3 per cent. It must be remembered in this connection that during 1910 the bacteria efficiency was 99.36 per cent.

We consider this most remarkable, showing as a positive proof the value of hypochlorite, especially in strengths of ½ to 1 part powder, corresponding to $\frac{1}{8}$ to $\frac{1}{3}$ part chlorine.

CONCLUSIONS.

As constructed at present, using hypochlorite, the Torresdale filtration plant can and does produce an effluent that is almost entirely free from pathogenic bacteria, that is, perfectly safe to use without boiling or further treating, but one that is not always clear.

A plant constructed as Torresdale, without any sedimentation basin, is utterly unable to cope for any prolonged period with water having a turbidity of over 100, that is, with the slow sand filters operating at a six million rate. When such a condition is reached, the pre-filters fail to do their proportion of work, and the final filters choke badly, allowing fine silt to pass through them. This choking necessitates cleaning for twenty-two hours a day, with 55–58 filters doing the work of 65 and depending on hypochlorite to reduce the number of bacteria and destroy the pathogens, which it does.

Fortunately the periods of turbid water occur but seldom and are of short duration.

The pre-filters should be changed and operated like the coal filters at Steelton, or a sedimentation basin should be constructed, using alum to coagulate the water.

But, to summarize, including the very worst periods the bacterial efficiency of the Torresdale filter plant averages over 99.5 per cent.; the water is clear and sparkling at least forty-eight weeks of the year, and is perfectly safe to drink at all times.

DISCUSSION.

PROF. GEORGE C. WHIPPLE.* This is one of the largest filter plants in the world, perhaps the very largest, and up to the present time we have not been able to study the results of its operation. This Association should consider itself fortunate in having these data presented to it. There are many interesting points of detail in this paper.

The frank admission that the preliminary filters have failed to do the work that was expected of them is important but not surprising to those who have studied the theory of their action. These preliminary filters act virtually as sedimentation basins, and it seems to me that it is perfectly natural that they should give a higher efficiency in the summer, when the water is warm, than in the winter when the water is cold and more viscous. That is generally true of sedimentation, and it is also true of filtration. The results shown here at Torresdale follow the theory very closely.

In the analyses of water before and after filtration which Mr. West has given us we find merely average figures arranged by months. This is the common practice, but when I think of the thousands of analyses that must have been made in his laboratory, three times a day at very many different places, and when I compare this very large number with the simple averages by months that he has shown us, it seems to me that a good deal has been lost from the record, and that we are not getting all of the information that we would like to get. This is not true of Mr. West's paper alone; it is true of almost all reports of filter plants that are published to-day. I feel that something is wrong in the way in which we use the information that we accumulate at so much time and expense. What we really want to find out in regard to a filter plant is whether it is operating regularly, whether it is giving good results, day by day, and hour by hour. Monthly averages do not tell us this. It seems to me that it is high time that as engineers we took this matter up and discussed it in all seriousness, to see if we cannot devise some better way of using the information that we are getting than we are doing at the present time. And I think that it would be very fitting for this Association to have a

* Professor Sanitary Engineering, Harvard University.

committee appointed to consider this matter, not only the subject of analyses, but all other statistical facts in connection with the operation of filter plants.* A large percentage of the water that is served to the people of this country to-day is filtered water, so that the subject is one of wide import.

I hope that Mr. West will include in the further discussion of his paper some of the diagrams which he has placed upon the screen this evening, and also some of the photographs and cost data. I am sure we should all be glad to have them in the JOURNAL. We are certainly very much indebted to Mr. West for his valuable contribution to the literature of filtration.

MR. JOHN H. GREGORY.† Mr. West's paper on the Torresdale filter plant is one which is extremely interesting to the speaker, as he was formerly connected with the city of Philadelphia and was in charge of the design of the slow sand filters. There are many interesting points that could be taken up in connection with the design and operation of the plant, but the time at our disposal is too limited to more than consider one or two.

Mr. West has spoken about one method of cleaning filters, that is, scraping and piling, without removing the sand from the filters, and stated that it had been used at Torresdale. It may be of interest to say that the same method was used at Albany, N. Y., in 1899. It was shortly after we started the slow sand-filter plant there, and it was possibly in the second or third run of the filters. The plant at Albany was started up under somewhat similar conditions to those at Torresdale; that is, the plant was not finished, but it was desired to furnish filtered water to the city at as early a date as possible. At that time the sand washers at Albany were not complete, nor was the court entirely paved. The first filter runs had been made and it became necessary to clean the filters. The sand was taken out from several filters and piled in the paved part of the court. In the other filters, as there was no opportunity to store the sand outside, the means was resorted to of scraping and piling the sand in the filters, after which the filters were put back in operation. As far as the speaker knows, that was the first time that this method was used in this country.

* For further discussion on this suggestion and appointment of committee see page 465.
† Consulting Engineer, New York.

At the time that the slow sand filters at Torresdale were designed, the question of whether to build a sedimentation basin or preliminary filters for the preliminary treatment of the Delaware River water had not been definitely settled. The city was then experimenting at the Spring Garden testing station with sedimentation and also with preliminary filters. One of the original schemes considered was the construction of a sedimentation basin, practically out in the river, on the east side of Delaware Avenue and north of the present pumping station, and to pass the water through it before pumping it to the filters. The building of the preliminary filters instead of a sedimentation basin was not decided on, however, until some time after the speaker had severed his connection with the Philadelphia work.

It occurred to the speaker, when Mr. West was speaking about the character of the Delaware River water changing with the swing of the tide, that had a settling basin been built it would have been advantageous to operate it along the lines that the speaker observed when he visited the Antwerp filter plant. The practice there is to pump the water from the river to the settling basin at practically the end of the ebb tide; when the tide turns and comes back up the river they shut off pumping and wait until near the end of the next ebb tide before resuming. By this method of operation they get a very much better character of water to purify. The river from which the water supplied to Antwerp is obtained is more or less polluted at the water-works intake, especially so when the tidal currents are running upstream.

Mr. John C. Trautwine, Jr. Mr. West's paper refers primarily to the quality of water; but, between the lines, we may read an important message on that question of quantity which is the all-important question, underlying the entire problem of the Philadelphia supply. The merits of this question are so well known to all present that any extended discussion of it here would be inexcusable; but I am tempted to say a word, in view of the suggestions in Mr. West's paper, and especially in connection with what Mr. Gregory has just told us about the operation of the plant at Antwerp.

Referring to the early days of the Torresdale plant (1908), Mr. West uses the significant words: "Quantity became all im-

portant; quality was a decidedly second consideration"; and he tells us that those in charge were glad to take refuge behind the fact that, rich as their effluent then was in impurities, it was a distinct improvement upon the awful stuff which the city fathers forced me to pump while I was in nominal charge of the Philadelphia Water Bureau.

Near the close of his paper, Mr. West says: "We are putting out more water than would supply London," a city with about four times our population. Allowing for difference of legitimate use, between the Londoners and ourselves, we are safe in saying that we are expensively pumping, filtering, storing, and distributing more than twice as much water as our people, with their best efforts, can possibly use and enjoy, more than half of this filtered water being thrown into the sewers unused; and this in spite of the fact that four fifths of our people are using water reasonably, the entire waste being perpetrated by the remaining one fifth, who themselves derive no benefit from the waste.

As a result, the works are strained, night and day, in their efforts to fill a sieve; and the taxpayers are constantly threatened with more big bills for more big works which are not needed; the present works being more than ample (under common-sense methods) for a city twice our size.

Mr. Gregory has just told us that, at Antwerp, the works are shut down during the flood tide which brings polluted water to the intakes, the use of this polluted water being thus avoided. Such a course is impossible with us, because the works must be driven twenty-four hours per day, to avoid shortage. This of course precludes also the making of essential repairs, and the works are therefore undergoing rapid deterioration.

In the matter of quality, the Philadelphia works are incomparably ahead of the conditions which obtained during the dark and gloomy days of my chiefship; but, as to quantity, there has been but little if any improvement; and the pathetic part of it is that there is no need for such a situation.

Those at present in charge of the Department of Public Works have announced their desire to curtail the waste; and the city charter expressly places the direction, control, and administration of the works in the hands of that department, expressly prohibits

the city councils from interfering with or directing the exercise of the executive functions of the department, and expressly commands the city councils to provide for the proper and efficient conduct of the works by the department.

If the city charter means anything, it means that the direction of the public works shall be taken out of the hands of a body of butchers, bakers, candlestick makers, and bartenders, and placed under the control of men presumably qualified, by education and experience, to understand the problems involved.

And yet the city councils, disobeying the city charter, and usurping the functions given by the charter to the department, do interfere with and presume to direct the exercise of those functions, and they do not provide for the conduct of the works by the department.

We are told that we must submit to the deplorable results of the prodigious and preposterous waste, because, forsooth, city councils forbid the department to restrict the waste in its own way, and refuse to provide the necessary funds.

I long to see the administration go into court, dragging councils in by the nape of the neck, and compelling them, by mandamus, to perform the duties imposed upon them by the city charter.

I understood Mr. West to say that he was not prepared to give us the costs of filtration under the present method used. Is there any one else present who can give us that?

Mr. Joseph S. V. Siddons. I think I can give you that information. The cost of removal for the first year, 1908, was $2.44 a million gallons; for the piling, 57 cents a million gallons; the Brooklyn method was $1.64, the Nichols method $1.96; the rake filters cost us 18 cents a million gallons. In 1909 the Nichols method had dropped to 81 cents a million gallons, the removal to 67 cents, and the first rake was 7 cents a million gallons, the second rake 11 cents, and the third rake 15 cents. The piled filters were 54 cents a million gallons; and then seven filters were raked after they had been piled. For this we got the water at 18 cents a million gallons. In 1910 the Nichols method was 91 cents a million gallons and 38 cents per cu. yd.; the removal was $1.21 a million gallons and 41 cents a cu. yd. of sand. First rake cost 8 cents; second rake cost 13 cents; third rake cost 19 cents. At

that time we started to resand with the Nichols machines and that cost us 25 cents a cu. yd. during that year. In 1911 the Nichols method was still 38 cents a cu. yd., with $1.04 per million gallons, and the removal 54 cents a cu. yd. and 87 cents per million; the piling was 44 cents. First rake cost 6 cents, second rake cost 12 cents, resanding cost 31 cents per yd. The reason for the increase on resanding was due to the fact that in the case of the first filters that we resanded by the Nichols method the sand was taken from the bins right in front of the doors, and of course we had a longer throw from our sand bins into our filters. In 1912 we had $1.28 for the Nichols method and $2.13 for removal. And, by the way, the reason of that high cost for removals was that we did not take more than 2 in. of the penetration from our filters. We had at that time (1912) penetrations as great as 16 in., although the average was about 12 in. On the rake filters the first rake cost 5 cents and the second rake 9 cents. We did not undertake to rake the third time in 1912, because we found that the second rake was not giving us what we would expect from those filters. The average at that time was forty-five million gallons per filter, giving us only fourteen days' run. Instead of doing that, we piled the filters; some of our filters we piled the second time. We spaded one, two, and three times. As Mr. West said, we used every method that it was possible to in order to get the water. The resanding, which was done with the Nichols machines, was 26 cents a million gallons.

To summarize those figures and to take them for all four years, the cost of the Nichols method was $1.09 a million gallons and 37 cents a cu. yd.; the removal method cost $1.51 a million gallons and 40 cents a cu. yd.; the resanding was 25 cents a cu. yd. The raking up until the beginning of 1912 cost us about $5.50 per filter; but at that time we devised another method, that is, we changed the method of raking, and brought it down to $4 per filter. This gave us 5 cents for first rake, 8 cents for second rake, and 32 cents for third rake, for the average for the four years, although we did get as low as 3 cents per million gallons for first rake.

Possibly it would be interesting to compare the different methods for yields. At the start, as Mr. West said, the average was 47

million gallons filtered daily. The Brooklyn method average was 19 million gallons; the average for removal was 74 million gallons, and 379 million gallons for the maximum. The average was 150 million gallons for the Nichols method, which was double any of the other methods, and 569 million gallons for one filter from the Nichols method. That was a run of one hundred and forty-eight days. We consider that a rather remarkable run — 569 million gallons. The spaded filters gave us 51 million gallons for an average and 90 million gallons as the maximum. Filters raked once, 85 million gallons; filters raked twice, 52 million gallons; filters raked three times, 41 million gallons; piling, 35 million gallons. Of course, as one of the gentlemen said, these figures are averages, and in order to get down to a detail it requires rather a lengthy article to get these things out. I believe that Mr. Hardy, in charge of the Washington plant, had one in the Journal of the American Society of Civil Engineers* some time ago, and his was quite a lengthy table. But I will say that our filters for forty-eight weeks in the year (or very nearly all of that time) gave us filtered water at an average of about 99.2 removal, with a bacteria count of less than one hundred.

MR. JOHN A. KIENLE.† Mr. President, the speaker has been much interested in the paper which Mr. West has presented, and also its discussion, particularly that portion dealing with the question of economical methods of filter sand washing. As chief engineer of the Water Department at Wilmington, Del., the speaker had considerable experience with the method of cleaning filter sand by the use of Blaisdell's Filtration Company's washing machines. This method is strictly mechanical and a full description of it can be obtained by reference to the annual reports of that department. At that time the speaker's recollection in regard to the cost per million gallons of the Blaisdell method of cleaning is that it was about $1.10 in the second year of the operation of the plant, which compares with what Mr. Siddons has said with regard to the Nichols method of cleaning. During the time I was connected with that plant I watched very closely the articles appearing in the engineering papers regarding the cost of filter cleaning, particu-

* Trans. Am. Soc. C. E., vol. lvii, 307; vol. lxxii, 301.

† Sanitary Engineer with Electro Bleaching Gas Company, New York.

larly of the slow sand type, and it is my present recollection that there were no lower costs than those obtained at Wilmington by the use of the Blaisdell machine.

The Nichols method has been discussed quite extensively, and one feature in connection with it which the speaker discussed with a number of gentlemen is the question of the loss of fine sand due to its escape with the turbid water during the washing process. It is the speaker's belief that it would be of interest to the members of the Association to have Mr. West embody in his summary of remarks for the discussion a statement regarding the effect of the loss of this fine sand. In one instance, in discussing this question with a gentleman who was in charge of another plant, there was some thought that this loss of fine sand would have to be replaced. Whether that is actually the case or not, however, is open to question.

The speaker was interested also in Mr. West's remarks regarding the organic matter, particularly his statement to the effect that this subject had not been thoroughly studied and presented before the several associations; that is, the effect of the organic matter. He distinctly recalls that, shortly after the beginning of the operation of the Wilmington plant (it had been in operation something like three months, through the early spring), in March during a very warm period the water from the sedimentation basin after some three or three and a half days' storage had as much as two thousand microscopic organisms per cubic centimeter. And this water was discharged on to the filters at the time when we were not making regular microscopic examination of the water. Inside of seventy-two hours the entire plant was out of service. This would have resulted in delivering the raw water from the reservoir to the city if it had not been that the Blaisdell machine came to our assistance. With it we were able to wash a one-third acre bed in about four hours, and get it back in service again. That really shows one advantage of this method of cleaning. In addition, the method has the advantage of reducing the first construction cost by reason of the filter area required. That is to say, the time out of service of any section of a filter plant increases the total area of that plant very materially, in order to have ample reserve during the washing period. This reserve area is very

materially cut down by the use of the Blaisdell method. The speaker would not want to say positively (it is a matter of record in the Wilmington Water Department reports), but it is his recollection, that there was only five per cent. of the time that the filters were out of service, while in the ordinary slow-sand plants, with the ordinary methods of cleaning, this time out of service is very much more than that I have stated. The method of raking the filters, which has within the last three or four years come into use, can also be adopted with the Blaisdell machine. At Wilmington we found that following a washing with the machine the yield was not as great as following a raking with the machine. In order to machine rake the filters, the water was drawn off the surface of the bed, the machine being then passed over the bed, the teeth through which the water is ordinarily injected in the washing process effecting the raking very much more thoroughly on the bed and to a greater depth than can possibly be obtained by hand rakes; in fact, it is very much more uniform. The speaker's recollection is that the increased yield due to this mechanical raking was almost 100 per cent. In other words, a yield that might be something like thirty million gallons per bed would be raised by washing to possibly as much as sixty million gallons.

Mr. J. S. V. Siddons (*by letter*). The following tables show the actual labor cost per million gallons and per cubic yard of sand washed. By the actual labor cost, is meant, the cost of cleaning from the time the sand-run door is opened until the laborers are out and have moved the washing machinery to the next filter to be cleaned. This also includes the cost of raw water used for washing sand, for which we charge ourselves $5 per m.g.

The laborers receive $12 per week of 44 hr., or 27.3 cents per hour.

The total cost of operation per million gallons filtered for 1912 is shown in the following table; this includes 2 cents per m.g. for clerical force on filter records at City Hall; also 12 cents per m.g. for coal used for pumping pre-filtered wash water used at the preliminary filters, power to operate blowers at the pre-filters, and coal used to heat the laboratory and treatment house.

These figures include all the materials used in the operation of the plant, also cost of bleach used in the hypochlorite plant. The cost of pumpage is additional to the above.

TABLE 15.

	Number of Filters.	Yield, Million Gallons.						Days Run.			Cost, Dollars.			
		Total.	Max.	Min.	Av.	Acre.	Rate.	Max.	Min.	Av.	Total.	Filter.	M.g.	Cu.yd. Sand.
1907														
Start	55	.....	60	18	37	49	1.8	71	11	28	.....	.....	...	...
Brooklyn, 07–08	609	11 345	67	4	19	25	1.8	49	6	14	19 521.44	32.09	1.72	...
1908														
Start	10	.....	73	47	59	79	1.2	77	63	65	.....	.....	...	...
Remove	282	11 028	80	19	39	52	2.6	45	10	20	26 907.30	95.42	2.44	.40
Piling	530	18 321	69	17	35	46	2.4	42	10	19	10 541.45	19.89	57	...
Brooklyn	216	3 921	61	4	18	24	1.6	42	6	15	6 407.68	29.67	1.64	...
Nichols	5	365	108	42	73	97	2.2	60	30	45	715.86	143.17	1.96	.47
Raked	24	948	66	24	39	52	2.2	37	16	23	174.40	7.27	.18	...
Resand	27	.....	...	...	...	...	...	...	...	...	8 678.88	.....	...	.24
	1 057	34 583	...	...	33	44	2.3	...	...	19	53 425.57	.....	1.54	.51
1909														
Nichols	229	28 244	519	51	123	164	4.5	122	16	34	22 942.85	100.19	.81	.44
Remove	62	11 973	379	37	193	257	4.3	105	11	60	8 027.21	129.47	.67	.34
Rake 1	260	20 828	280	20	80	107	5.3	75	6	20			.07	...
Rake 2	151	8 492	116	17	56	75	4.4	37	7	17	2 839.61	5.93	.11	...
Rake 3	68	2 775	73	17	40	53	4.8	24	5	13			.15	...
Piled	77	3 249	142	12	43	57	3.6	57	4	16	1 761.67	22.82	.54	...
Piled and rake	7	560	198	43	80	107	4.6	49	12	23	100.29	14.32	.18	...
Resand	37	.....	...	...	...	...	...	...	...	...	10 353.68	.....	...	.23
	854	76 121	...	...	87	116	4.6	..	...	25	46 025.31	.....	.61	.38

1910														
Nichols	232	45 196	569	68	195	260	4.5	148	27	58	41 177.72	177.49	.91	.38
Remove	71	8 390	291	56	118	157	4.4	91	20	35	10 151.76	142.98	1.21	.41
Rake 1	236	19 927	246	25	84	112	4.3	60	11	26			.08	...
Rake 2	107	5 618	116	16	52	69	4.1	33	8	17	2 255.55	6.50	.13	...
Rake 3	4	141	47	23	35	47	3.4	23	10	14			.19	...
Resand	14	.....	...	...	...	...	...	...	...	...	3 466.33	.....	...	.25
	650	79 272	...	...	122	163	4.5	...	...	36	57 051.36	.....	.88	.39
1911														
Nichols	265	42 465	401	49	160	213	4.3	102	20	50	44 228.11	168.89	1.04	.38
Remove	20	1 625	195	50	81	108	4.1	63	19	27	1 418.97	70.98	.87	.54
Rake 1	259	25 253	237	38	98	130	4.8	72	11	26			.06	...
Rake 2	84	4 136	120	21	49	65	4.6	31	8	14	2 008.34	5.84	.12	...
Rake 3	1	53	53	53	53	71	3.7	19	19	19			.11	...
Piling	3	167	72	38	56	75	5.3	19	10	14	74.64	24.88	.44	...
Resand	14	.....	...	...	...	...	...	...	...	...	3 376.65	.....	...	.31
	632	73 699	...	...	117	156	4.5	...	...	35	51 106.71	.....	.69	.38
1912														
Nichols	303	38 866	289	30	126	168	4.3	80	11	39	49 704.63	164.04	1.28	.35
Remove	82	5 251	187	10	64	84	5.0	55	4	17	11 163.06	136.14	2.13	.43
Rake 1	257	21 270	182	3	83	111	5.0	50	2	22			.05	...
Rake 2	66	2 987	79	16	45	60	4.3	24	6	14	1 268.72	3.93	.09	...
Piling 1	37	1 249	70	3	34	45	5.0	18	2	9			.82	...
Piling 2	5	198	50	20	40	53	4.1	22	7	13	1 161.24	27.65	.70	...
Spading 1	50	2 700	90	11	54	72	4.2	22	4	17			.29	...
Spading 2	14	590	65	30	42	56	5.1	16	9	11	1 010.05	15.54	.37	...
Spading 3	1	32	...	...	32	43	4.8	...	...	9			.49	...
Resand	18	.....	...	...	...	...	...	...	...	...	4 970.57	.....	...	.26
	815	73 143	...	...	90	120	4.6	...	...	26	69 278.27	.....	.95	.37

TABLE 15.—*Continued.*

SUMMARY, 1907–1912.

	Number of Filters.	YIELD, MILLION GALLONS.						DAYS RUN.			COST, DOLLARS.			
		Total.	Max.	Min.	Av.	Acre.	Rate.	Max.	Min.	Av.	Total.	Filter.	M.g.	Cu.yd. Sand.
Start	65	2 654	73	18	47	63	1.9	77	11	34	.....	.....	...	...
Brooklyn	609	11 345	67	4	19	25	1.8	49	6	14	19 521.44	32.09	1.72	...
Remove	517	38 267	379	10	74	99	3.6	105	4	27	57 668.30	111.54	1.51	.40
Nichols	1 034	155 136	569	30	150	200	4.4	148	11	45	158 769.17	163.22	1.09	.37
Rake 1	1 036	88 226	280	3	85	113	4.7	75	2	24	.....	.....	.05	...
Rake 2	408	21 233	120	17	52	69	4.6	31	6	15	8 546.62	*5.56	.08	...
Rake 3	73	2 969	73	17	41	55	3.9	24	5	14	.....	.....	.32	...
Piling	652	23 184	167	3	35	47	2.6	19	2	18	13 539.00	20.76	.58	...
Piling and rake	7	560	198	43	80	107	4.6	49	12	23	100.29	14.32	.18	...
Spade	65	3 322	90	11	51	68	4.5	22	4	15	1 010.05	15.54	.37	...
Resand	110	.....	...	...	...	...	...	...	...	...	30 846.11	280.42	...	.25
	4 466	346 896	...	...	78	104	4.5	...	...	26	290 000.98	.....	.84	.36

*1912, 4.00.

COST OF OPERATING FINAL FILTERS PER M.G. FILTERED.

Office	$0.08	
Filter attendant	.13	
Cleaning sand	1.00	
Labor on grounds	.04	
Maintenance and repairs	.10	
Laboratory	.16	
Lighting	.05	
Treatment	.09	
Janitor and watchman	.02	=$1.67

COST OF OPERATING PRELIMINARY FILTERS PER M.G. FILTERED.

Filter attendant	$0.14	
Labor on grounds	.02	
Maintenance and repairs	.08	= .24
Total cost per million gallons		$1.91

The total cost per million gallons filtered since operation was started has been as follows:

Year.	Pre-Filter.	Final Filter.	Total.
1907*	....	....	$3.75
1908	....	....	2.80
1909	$0.26	$1.44	1.70
1910	.30	1.52	1.82
1911	.28	1.38	1.66
1912	.24	1.67	1.91
1913†	.22	1.50	1.72

* Last six months. † First six months.

Table 16 gives the amount of sand handled.

TABLE 16.

CUBIC YARDS OF SAND HANDLED.

	NICHOLS METHOD.		REMOVAL METHOD.		RESANDING.		Total.
	Totals.	Av. per Filter.	Totals.	Av. per Filter.	Total.	Av. per Filter.	
1908.....	1 529	306	67 335	239	36 162	1 339	105 026
1909.....	52 567	229	23 227	375	45 016	1 217	120 810
1910.....	109 092	470	24 707	348	13 716	980	147 515
1911.....	120 257	452	2 655	133	11 021	787	133 933
1912.....	141 136	466	26 595	324	18 912	1 056	186 643
	424 581	411	144 519	279	124 827	1 134	693 927

The following figures show the cost of handling sand and some wash-water data.

Average cost to scrape one cu. yd. of sand	$0.15
Average cost to wash one cu. yd. of sand	.20
Average cost per cu. yd. to move machinery to next bed	.02
Total average cost	$0.37
Volumes of water to sand	6
Cu. yd. of sand per m.g. filtered	1.9
Average cu. yd. of sand washed per hr. (Nichols method)	7
Wash water per cent. of total yield, preliminary	.6%
Wash water per cent. of total yield, finals	.4%
Wash water per cent. of total yield, total	1.0%

NOTES ON WATER WASTE PREVENTION WORK IN NEW YORK CITY.

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[*Read September 10, 1913.*]

Conservation of resources and elimination of waste are to-day receiving preferential attention by both municipal and private corporations, and in the past three years New York City has accomplished results along these lines in her water-supply system, unequaled, it is believed, by any other municipality. In 1910 New York had a per capita consumption of 111 gallons, which was lower than that of seven out of the first ten American cities, as shown by the following table:

City.	Estimated Population, 1912.	Daily Water Consumption per Capita. 1912.	1910.*
New York.....	5 053 000	100	111
Chicago.....	2 350 000	199	235
Philadelphia.....	1 600 000	200	203
St. Louis.....	710 000	118	109
Boston.....	718 900	125	130
Cleveland.....	660 000	111	102
Baltimore.....	569 000	128	115
Pittsburg.....	517 000	236	197
Detroit	566 000	185	177
Buffalo.....	450 000	310	321

Even with this comparatively low consumption, during less than three years water-waste work, New York has reduced her total consumption from 525 m.g.d. to 486 m.g.d. If allowance be made for the normal three per cent. yearly growth in population, this reduction is equivalent to 90 m.g.d., or more water than the present supply of St. Louis or Boston, with their population of nearly three quarters of a million.

As this reduction has come from a net expenditure of about one hundred thousand dollars and a gross expenditure of less than one hundred and fifty thousand dollars, the efficiency of the methods

*The figures given are, as far as possible, for the year 1910.

used cannot be questioned, and an outline of the work should be interesting to water-works officials.

Boroughs of Manhattan and The Bronx.

REASONS FOR UNDERTAKING WATER WASTE PREVENTION WORK.

The Boroughs of Manhattan and The Bronx obtain their supply from the watersheds of the Croton, Bronx, and Byram rivers. The continuity of the supply is absolutely dependent upon stored waters, as the run-off of the rivers is, at times, less than the evaporation.

In the spring of 1910, all the available reservoirs in the Croton Valley were full, and water wasted over the New Croton dam up to May 17, when there were 88 690 million gallons, stored in the nine reservoirs and six ponds which are available to hold the water from the 360 square miles that constitute the Croton shed. In the Bronx and Byram shed, covering 22 square miles, there are four reservoirs and ponds, holding 4 195 million gallons, and these were also full. The unprecedented dry season, commencing about July 1, 1910, resulted in a depletion of the stored water in the Croton basins, amounting to 50 583 million gallons by February 28, 1911, when the storage was only 38 107 million gallons. At this time there was little or no snow on the ground and no reasonable hope of heavy spring run-off to replenish the depleted storage.

The consumption at this time was running over 330 m.g.d., and the recorded flow for the Croton River from the year 1868 to 1910 showed that if this rate of consumption continued, and the run-off was no lower than that previously recorded, all the reservoirs would be empty by September. This would mean that there would be practically no water available for a community of three million people, as the flow of the river after a dry summer would be only a small fraction of the normal consumption from the Croton system.

The paralyzing of the industries of the greatest manufacturing city in America, the suffering of the people, and the danger to property and health that would result from a stoppage of the water supply even for a few days' time, constituted a menace to the welfare of the city so great that the Commissioner of Water

Supply, Gas and Electricity, Hon. Henry S. Thompson, immediately commenced, through the public press, to inform the citizens of the condition of the water supply and the need for conserving it. This publicity campaign was productive of results as shown by a reduction in consumption in the month of May amounting to 26 million gallons daily, as compared with the same month of 1910, allowing three per cent. for the normal yearly increase in population and consumption. As the dry weather continued, more radical measures were deemed necessary, and in May it was recommended that the following steps be taken:

RECOMMENDATIONS TO CONSERVE WATER SUPPLY.

1st. Printed notices be delivered at every building in Manhattan and The Bronx, stating the need for stopping waste and calling attention to the fine which the commissioner might impose if the waste was not stopped.

2d. House-to-house inspection to be made by a special corps.

3d. Pitometer work to be undertaken along the river-front, to detect leaks in mains or services.

4th. Surveys to be made and plans drawn for a temporary source of supply of about 50 million gallons daily capacity.

These recommendations were approved and the following notice was printed in English, Italian and Yiddish:

PRINTED NOTICE TO STOP WASTE OF WATER.

IMPORTANT.

To the Owner of the Premises:

To stop waste of water, an inspection is to be made of these premises, and your attention is called to the necessity of having all fixtures in good order, as the rules of the Department provide a penalty of two dollars ($2) for each leaky fixture. The fixtures which are ordinarily found out of order are tanks of toilets, faucets, and ball-cocks controlling overflow of tanks.

You are hereby notified to have all leaky fixtures repaired immediately.

The use of hose, either inside or outside of buildings, is prohibited.

It is hoped that you will do everything in your power to stop all unnecessary use of water so that we may avert as much as possible a situation which would be most serious.

HENRY S. THOMPSON,
Commissioner.

One hundred and fifty thousand copies of the above were delivered between June 6 and June 16, 1911, as follows:

1st. One hundred and forty-five thousand copies were delivered on the premises, without folding.

2d. In order to reduce waste in large buildings of various kinds, where the consumption of metered water was very great, and where the department did not intend to make an actual inspection, 4 855 notices were placed in envelopes and addressed to the owner, manager, superintendent, engineer, or janitor of large office buildings, apartment houses, department stores, steam plants, and delivered to the individual in charge.

3d. Where the premises to be notified were outside of the delivery limits of the private concern that was doing this work, notices were mailed, the total number of notices delivered in such manner being 145.

The following table shows the weekly consumption in June in Manhattan and The Bronx and in Brooklyn. As house-to-house inspection did not commence until the middle of June, and less than ten per cent. of all premises were covered in that month, the reduction in consumption noted must have been mainly due to the printed notices:

DAILY CONSUMPTION DURING JUNE, 1911, BOROUGHS OF MANHATTAN AND THE BRONX AND BROOKLYN.

	Million Gallons.	
Week Ending	Manhattan and Bronx.	Brooklyn.
June 3	283	139
June 10	292	137
June 17	279	135
June 24	289	139
July 1	282	142
Average	286	139
The corresponding figures for June, 1910, were	329	139

There was an evident reduction in consumption following the receipt of the notices, and this reduction increased during the month of July, the total reduction being estimated at about 25 m.g.d., or nearly nine per cent. of the supply in Manhattan and

The Bronx. Assuming that the reduction in waste would gradually lessen and entirely disappear in two years,* the total amount of water saved would be over 9 000 million gallons. As the cost of printing and distributing the notices was $1 388, the resultant cost was $0.15 per million gallons saved, or about one quarter of one per cent. of the average cost of water distributed in New York City.

INSPECTION OF BUILDINGS.

For the house-to-house inspection work a corps of about one hundred and fifty men was employed, there being on an average one clerk at $900 per annum for every four inspectors at $1 100 per annum. The inspectors worked in squads of from fifteen to twenty, in charge of two regular department inspectors. Every building was thoroughly examined, an average day's work of eight hours covering ten buildings.

After the inspection of the premises a notice was mailed by the department, addressed to "The owner or occupant of the premises," calling attention to the leaks found, and notifying the owner to make the necessary repairs to the leaky fixtures, the said form of address being approved by the corporation counsel as a legal notification. Three days were allowed from the date the notice was mailed before a reinspection was made, and if it was found that more than 50 per cent. of the leaky fixtures which had been discovered upon the first inspection had not been repaired, a fine of $2.00 was imposed. After an interval of about a week the premises were again inspected, and if the leaks had not been repaired an additional fine of $2.00 was imposed and this procedure was followed until fines, in some cases, had been imposed as many as seven times on the same premises. Where it was found, after several inspections, that the owner did not occupy the premises in question, his name and address was obtained and an individual notice sent to him, stating that if the leaks on the premises were not repaired, the water would be shut off after three days from the date of notice. In no case was this extreme penalty resorted to;

*This period of time is used simply as a basis of computation, the exact time required for the leakage to return to the amount existing prior to commencing water-waste work being unknown. It is estimated that at the present time, which is just two years after the house-to-house inspection, the reduction in consumption is about fifty per cent. of that shown immediately after the active campaign was stopped.

although in one case the department men had commenced to dig up the street in front of the premises to shut off the water, when the owner appeared and made immediate arrangements for repairing the leaks on the premises, after paying $9.00 for the work done by the department force in making preparations to shut off the water. The fines imposed became, under the laws of New York, a lien on the property, and therefore readily collectible. Fines were rebated when a satisfactory reason was given, showing inability to comply with the department order within the time allowed.

House-to-house inspection was carried on actively during July, August, and September, and then, owing to the crisis having passed, the force was materially reduced and finally disbanded at the end of the year.

The premises inspected were grouped in districts covering about one hundred city blocks, although the size of the districts varied materially. Pitometer gagings were made immediately before the inspection was commenced in each district, and immediately after the final inspection was completed.

These gagings indicated, as shown by Table 1, that the inspectors saved a maximum of 20 per cent. and a minimum of 2 per cent., with an average of 12.2 per cent., out of a total measured consumption of 175 m.g.d., which is 60 per cent., of the total consumption. The extent of the leakage found, even after the reduction due to the printed notices, is shown by Table 2, from which it will be seen that the number of leaky fixtures averages nearly three to each building. The estimated net cost of this inspection and pitometer work was about $60 000, after the fines were deducted, and even assuming that the leaks then stopped would gradually develop again so that the full amount of leakage reappeared in two years' time, the cost per million gallons would be about $7.70. Assuming an average of one hundred inspectors employed, the amount saved per inspector was 0.21 of a million gallons per day; but if the work had been spread over a longer time, the average per inspector would have been higher, as the cumulative effect of the longer period of work would be shown to the inspector's credit, while the cost would have remained about the same per million gallons.

TABLE 1.

SAVING OF WATER SECURED BY HOUSE-TO-HOUSE INSPECTION IN MANHATTAN, AS INDICATED BY PITOMETER GAGINGS OF CONSUMPTION.

District.	Character.	Daily Consumption before Inspection. Gallons.	Daily Consumption after Inspection. Gallons.	Daily Saving. Gallons.	Saving. Per Cent.
1	Tenement	8 284 000	6 600 000	1 684 000	20
2	Dense East Side tenements	11 444 000	10 613 000	831 000	7
3	Low-class tenements and apartments	14 823 000	12 710 000	2 113 000	14
4	High-class resident district	12 737 000	11 410 000	1 337 000	10
5	Dense East Side tenements	10 301 000	8 680 000	1 621 000	16
6, 8	Tenements and apartments	14 685 000	14 057 000	628 000	4
7	Medium-class apartments	13 378 000	10 894 000	2 484 000	18
9, 12	Medium-class apartments	13 660 000	12 400 000	1 200 000	9
10	High-class apartments	5 655 000	4 664 000	991 000	17
13, 14	High-class apartments	22 181 000	21 690 000	491 000	2
15	Hotel and theater district	29 482 000	23 559 000	5 923 000	20
17	Tenements and apartments	7 360 000	6 234 000	1 126 000	15
18	Business and warehouse district	10 790 000	9 944 000	846 000	7
Total		174 780 000	153 505 000	21 275 000	12.2 aver.

$$\text{Saving} \frac{21\,275\,000}{174\,780\,000} = 12.2 \text{ per cent.}$$

Cost of pitometer gagings	$22 950.00
Cost of inspectors, clerks, etc.	58 150.00
Total cost	$81 100.00

TABLE 2.

MANHATTAN—NUMBER OF MEN EMPLOYED, PREMISES EXAMINED, AND LEAKY FIXTURES FOUND DURING HOUSE-TO-HOUSE INSPECTION, JUNE TO DECEMBER, 1911.

Months.	Number of Inspectors, Average per Day.	Number of Clerks for Office Work, Average per Day.	Number of Premises Inspected.	Number of Leaks Found.	Per Cent. Premises having Leaky Fixtures.	Number of Premises Re-examined.	Number of Fines Imposed for Failure to Repair Fixtures.	Amount of Fines Imposed.
1911.								
June	87	13	12 834	47 370	75	2 716	303	$606.00
July	105	25	18 644	56 107	69	21 405	4 496	8 992.00
August	114	21	23 893	48 419	60	17 753	2 175	4 358.00
September	77	21	10 852	33 100	70	17 366	2 510	5 020.00
October	35	24	4 109	7 058	48	8 803	1 823	3 646.00
November	18	13	1 621	3 413	47	5 215	299	598.00
December	7	4	418	1 768	56	2 233	245	490.00
Total			72 371	197 235		75 491	11 855	$23 710.00*

* A small percentage of these fines were rebated.

FIG. 1.

MANHATTAN.

PARTIALLY BLOWN JOINT. LEAKAGE 29 000 GALLONS PER DAY.

FIG. 2.

BROOKLYN.

A BLOWN JOINT ON 4-IN. HYDRANT BRANCH.

LEAKAGE 300 000 GALLONS PER DAY.

LEAKAGE IN STREET MAINS AND SERVICES.

To stop waste from leaks in mains outside of buildings, surveys were made with the pitometer, the force employed consisting generally of an engineer in charge, two assistants, and six skilled and unskilled laborers. This work, especially that along the waterfront, was commenced in September, 1910, and carried on almost continuously until December, 1912, the only interruption being when the entire force was used in connection with pitometer gagings of districts covered by house-to-house inspection in the summer of 1911. The leaks discovered were generally from blown joints, broken pipes, and broken or split house services. The character of leaks is shown on Plate XXXI. The total amount of leakage checked by this work amounted to 16 672 000 gal. daily. In connection with the waterfront work there have been over 16 miles of river front examined, containing about 84 miles of mains, with a measured flow into districts of about 40 m.g.d., and leaks were stopped amounting to 10 m.g.d., of which 5.7 million gal. were found in submerged pipe lines.

The cost of this work was $19 000, and if it be assumed that, on an average, the leaks stopped would have been discovered by the regular maintenance force in ten years, the cost of saving this water would be about $0.50 per million gallons. This cost is based upon a sinking fund of 8.7 per cent. annually, and interest at the rate of 4.3 per cent. The leaks on the submerged lines were very large in proportion to the amount of time spent in locating and stopping the same, and therefore in estimating the cost per million gallons for saving the water, it would be reasonable to omit such large leaks. Assuming that the money spent represented the cost of stopping leaks amounting to 4.3 million gallons daily, the cost would be about $1.30 per million gallons.

Table 3 shows the results accomplished in the way of reducing leakage by appeals through the press, printed notices to stop leaks and unnecessary use of water, house-to-house inspection, and stopping leaks from mains and service pipes. In this table the amount credited to each cause is necessarily approximate, with the exception of the leaks from mains and defective services, but the table, nevertheless, gives some adequate idea of the relative

TABLE 3.

REDUCTION IN CONSUMPTION — MANHATTAN AND THE BRONX — 1911.

(Million gallons daily.)

CONSUMPTION.			Estimated Consumption assuming Increase 3%, Equivalent to Rate of Increase in Population, 1911.	ESTIMATED REDUCTION IN CONSUMPTION.				Total.
Month.	1910.	1911.		Press Publicity.	Printed Notices.	House-to-House Inspection.	By Stopping Underground Leakage.	
January	335	334	345	0	—	0	4	11
February	336	331	346	0	—	0	4	15
March	327	327	337	4	—	0	6	10
April	326	320	336	10	—	0	6	16
May	326	310	336	18	—	0	8	26
June	329	286	339	20	21	3	9	53
July	342	287	352	20	27	9	9	65
August	336	275	346	20	26	16	9	71
September	335	277	345	18	22	18	10	68
October	332	278	342	13	20	20	11	64
November	321	271	331	11	17	21	11	60
December	333	283	343	11	17	21	11	60

effectiveness of the means employed to reduce waste and unnecessary use of water.

METERED CONSUMPTION.

The metered consumption, which amounts to about 30 per cent. of the total for Manhattan and The Bronx, or 90 m.g.d., has remained practically constant during the water-waste work, the increase being only that due to normal growth. The reduction has, therefore, been confined to the unmetered consumption, and represents, as a maximum, a reduction of thirty per cent. of said consumption. The per capita consumption in Manhattan and The Bronx, before and after the water-waste work, was as follows:

Time.	Average Daily Consumption, Million Gallons.		Average Daily Consumption, Gallons per Capita.	
	Total.	Metered.	Total.	Excluding Metered Consumption.
January—December, 1910.....	331	84	120	90
January—June, 1911.....	318	89	112	81
July —December, 1911.....	279	89	98	67
January—December, 1912.....	303	90	104	73
January—June, 1913.....	304	90	102	72

In New York all water used for business purposes is metered, and the metered services in 1912 in Manhattan and The Bronx numbered 61 500 out of an estimated total of 92 300 metered services in the five boroughs.

It will be seen that, excluding metered consumption, the per capita consumption is low for a large city, but still materially above what is probably necessary for domestic consumption, indicating that the amount of leakage still remaining is large in total quantity although probably difficult and comparatively expensive to eliminate.

PER CAPITA CONSUMPTION.

The per capita consumption for the last twenty years is shown on Table 4.

From this table it will be seen that the drop in per capita consumption amounted to 30 per cent., i. e., from 134 gal. to 102 gal. This reduction commenced in about 1906, but the cause is not clear prior to the water-waste campaign in 1911. It was probably due, in a great measure, to business depression, New York City, as the financial center and the largest manufacturing city in the United States, very promptly feeling any dullness in trade and resulting reduction in manufacturing.

WATER-WASTE WORK IN THE FUTURE.

With the excellent and exceptionally low-cost results obtained, the continuance of the waste prevention work would be expected, but owing to the character of the Croton system, it was found to be

TABLE 4.

PER CAPITA CONSUMPTION, 1892–1913, MANHATTAN AND THE BRONX, AND BROOKLYN.

(Gallons daily.)

Year.	Manhattan and The Bronx.	Brooklyn.
1892	91	74
1893	96	79
1894	99	72
1895	100	75
1896	109	85
1897	115	88
1898	117	88
1899	123	88
1900	130	88
1901	129	86
1902	129	86
1903	128	85
1904	132	90
1905	134	91
1906	133	96
1907	131	101
1908	126	100
1909	122	95
1910	120	97
1911	105	92
1912	104	91
1913 *	102	78

* First 6 months.

TABLE 5.

BOROUGHS OF MANHATTAN AND THE BRONX, AVERAGE DAILY CONSUMPTION, 1903 TO MARCH, 1913, INCLUSIVE.
(Million gallons.)

Month.	1903.	1904.	1905.	1906.	1907.	1908.	1909.	1910.	1911.	1912.	1913.
January	294	300	314	320	340	325	316	335	334	302	292
February	292	310	320	323	353	340	316	336	331	310	306
March	290	299	319	320	344	329	317	327	327	299	301
April	284	294	315	318	329	325	316	326	320	297	304
May	285	296	313	317	323	322	321	326	310	299	307
June	283	307	315	328	328	340	330	329	286	308	314
July	292	300	323	331	334	342	330	342	287	309	...
August	287	301	318	316	330	330	329	336	275	305	...
September	291	307	318	332	323	329	335	335	277	309	...
October	285	305	321	330	322	321	334	332	278	300	...
November	284	302	322	326	314	313	322	321	271	297	...
December	290	311	323	337	316	309	314	333	283	297	...
Average	287	303	318	325	330	327	325	331	298	303	304

uneconomical to pursue waste prevention work by house-to-house inspection after the sufficiency of the supply was demonstrated beyond reasonable question.

With a gravity supply, which is the condition in Manhattan and The Bronx for about 75 per cent. of the consumption, and with ample aqueduct and reservoir capacity, there is practically no difference in cost when very little water is being drawn and when a full supply is being drawn from the watersheds. The same force has to be employed to care for the watershed, reservoirs, aqueduct line, and distribution system, so that the operation and maintenance cost is not affected by reduction in water waste. The trunk main capacity is, however, affected by the rate of draft, as said mains, in a large, well-designed system, are normally proportioned to the needs for domestic consumption, with some margin for fire purposes. For about every 20 m.g.d. added to the consumption, a 48-in. main has to be laid; so that for each 20 m.g.d. saved, the laying of a 48-in. main can be eliminated. By taking the average length of trunk main required to deliver water from the end of the aqueduct to the center of distribution, and determining the cost of such a main, the monetary value of water saved can be arrived at, assuming there is no reason to save water to prevent extensions to the supply system, which was the case in Manhattan and The Bronx in 1912. Thus, from the terminal of the aqueduct at 135th Street gate house, Manhattan, to the center of distribution, is estimated at 25 000 ft. The cost of laying a 48-in. main in Manhattan streets is estimated at $18.00 per ft., making the cost of such main $450 000. Assuming the capacity of the 48-in. main to be 20 m.g.d., the cost per million gallons capacity would be $22 500. Assuming interest, sinking fund, and maintenance at 5½ per cent., the cost would be $3.39 per million gallons. As the lateral distributors in the distribution system are of a capacity based almost entirely on fire service requirements, there would be no additional saving for such parts of the system, even if the consumption were to be reduced, say 20 per cent.

For the pumped supply, the cost of maintenance and operation, including sinking fund on equipment, is equivalent to about $10.00 per million gallons.

From the above it is evident that for the present there is no financial return from reducing water waste where the cost of such saving exceeds $10.00 per million gallons in districts where the water is pumped and $3.39 per million gallons in districts where the water is delivered by gravity.

When the Catskill water supply is introduced and has been utilized to such an extent that pumping from the Brooklyn system will have to be resorted to if waste of water is not curtailed, a very different financial problem will be presented, and discussion of this problem at the present time is inopportune.

CONTROL OF LEAKAGE FROM MAINS AND SERVICES.

While financially the house-to-house inspection part of the water-waste prevention work was uneconomical after the fall of 1911, the measurement of flow in mains to detect underground leakage was continued, the force, however, being assigned at times to other work. This work resulted in the discovery and repair, during 1912, of about 33 leaks, divided as follows:

Broken mains	5
Joints	19
Defective services	9

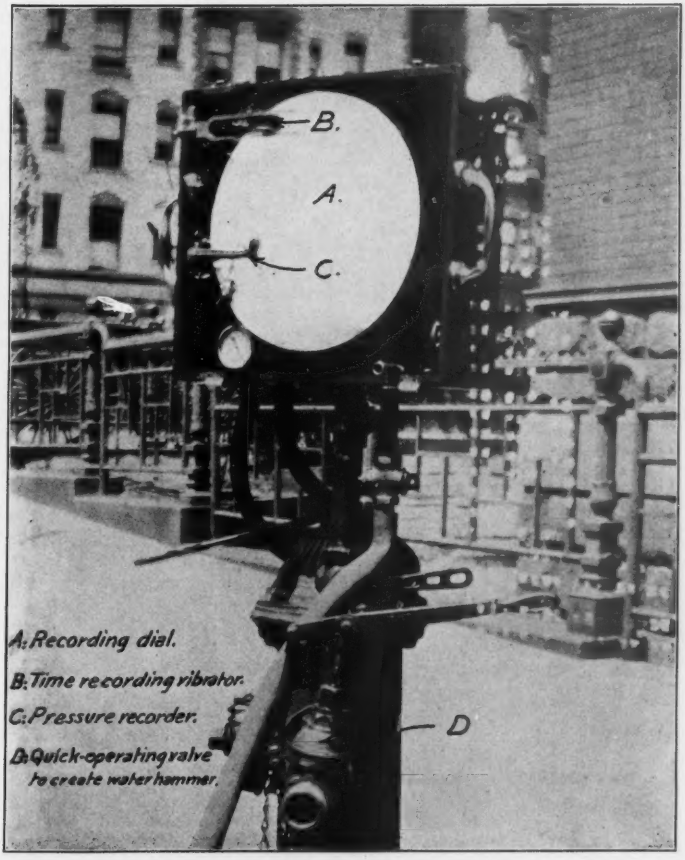
These leaks amounted to 3.8 m.g.d., while the total cost was about $16 000. Assuming that, on an average, these leaks would have been discovered by the regular maintenance force in ten years, the cost of saving the water would be about $1.50 per million gallons. This cost is based on a sinking fund of 8.7 per cent. annually and interest at 4.3 per cent.

The conditions in Manhattan and The Bronx are unusually favorable to the development and continuance of leaks from mains and services outside of buildings, without any indication on the surface. Owing to the rock floor being near the surface, much rock is removed in grading streets and excavating for buildings, the same being used to bring to grade streets crossing hollows. Also, in rock underlaid streets, the water main is usually laid in the sewer trench and the filling offers comparatively free passage-way for the leaking waters to reach the sewer. Under the above conditions, leaks amounting to several hundred thousand gallons

daily might continue for years without discovery from the appearance of the surface, and leaks of 100 000 gallons daily have been found only after pitometer measurements have shown unreasonably high flows.

To simplify the location of these leaks and to reduce the cost of such location, the department has recently used a "pulsograph," invented by Mr. N. Akimoff, of Philadelphia, which is shown in Plate XXXII. This instrument is based upon the water hammer experiments made in Russia in 1897–98 and reported in paper by N. Jonkowsky before the Russian Technical Society, April 29, 1898. It consists essentially of a large sensitive pressure recorder having a rapid motion, a tuning fork vibrating at a rate of 200 per second, and a quick-operating valve which is on a blow-off or by-pass pipe.

The instrument is set up by screwing it to a hydrant nozzle, the hydrant being chosen so that there will be a straight run of several hundred feet before an open four-way branch is encountered. By closing valves on intermediate branches, the effect of a long isolated line can be obtained. In operation, the valve on the main below the hydrant is closed, and water allowed to flow from the hydrant through the by-pass on the instrument. By quickly closing the by-pass valve, a water hammer of about fifteen pounds is created and recorded on the pressure gage. This pressure is maintained until the water-hammer pressure has reached the open branch at the end of the pipe line that is being tested and the drop in pressure has traveled back to the hydrant, the tuning fork vibrations showing the time for this double travel. By dividing twice the distance along the main to the open branch by the time, the rate of travel for the particular pipe is determined. This has been found to be approximately 4 200 ft. per second for 6-in. pipe and decreasing to about 3 600 ft. for 12-in. pipe. If there is any leak in the main, or in a service near the main, the water-hammer pressure is materially reduced by said leak and the chart shows separately the reduction due both to the leak and the open branch. The distance to the leak can then be determined by the time shown on the chart for the water-hammer pressure to travel to the leak and return to the pulsograph, this being multiplied by the determined rate of travel of the hammer pressure along the pipe, and divided



PULSOGRAPH IN PLACE ON HYDRANT.

by two. Several leaks have been located within limits of less than twenty feet by the use of this instrument, and the results from its further use should be interesting, as a decided saving in cost of locating leaks is anticipated.

TEMPORARY SUPPLY FROM TEN MILE RIVER.

Mention has been made of the recommendation to develop an additional temporary source of supply to meet the threatened danger of water shortage in the Croton Valley. The source selected was the Ten Mile River, a branch of the Housatonic. Surveys were made, and plans, specifications, and contract prepared for the utilization of this supply, at an estimated cost for construction of about $1 200 000, and for operation and maintenance, $183 000 annually. By October, 1911, the heavy rains and resultant run-off, together with the reduced consumption, had relieved the situation sufficiently to make it practicable to stop further work on this project, and no money was actually expended for an additional supply other than in connection with the surveys, preparation of plans, etc.

METHOD OF DETERMINING MINIMUM STORAGE REQUIRED IN CROTON VALLEY.

An interesting phase of the determination of the need for an additional supply was the fixing of the reasonable safe limit of depletion of storage on January 1 of any year. The Rippl, or mass curve method, is usually adopted in determining the safe maximum draft from any watershed. The run-off from the watershed is plotted for the entire period covered by the records, and a line is drawn representing the maximum draft on the assumption that all water stored in reservoirs would be used during the drought period, if such period were to recur. On this assumption it would be necessary that the run-off become equal to or greater than the draft on the day following the withdrawal of the last of the stored water from the reservoirs, and that the run-off would be sufficient thereafter to eventually refill the reservoirs.

While, theoretically, an engineer might assume such a rate of draft, the operating engineer responsible to nearly three million people for maintaining a continuous supply from sources depend-

ent entirely, at times, upon stored water, would be foolhardy if he allowed the storage to be depleted to such an extent. The rule adopted for New York was that the storage should not go below an amount which, added to the lowest run-off recorded for a year, would equal the anticipated consumption for such year.

The lowest recorded run-off of the Croton watershed for a calendar year was 207 m.g.d. With the consumption reduced to 275 m.g.d., the deficiency was 68 m.g.d., or 24 820 million gallons in one year. As further reduction could at that time have been made in the consumption, if necessary, the figure of 20 000 million gallons was adopted for New York conditions in 1911.

Fig. 1 shows the mass curve of flow of the Croton River during

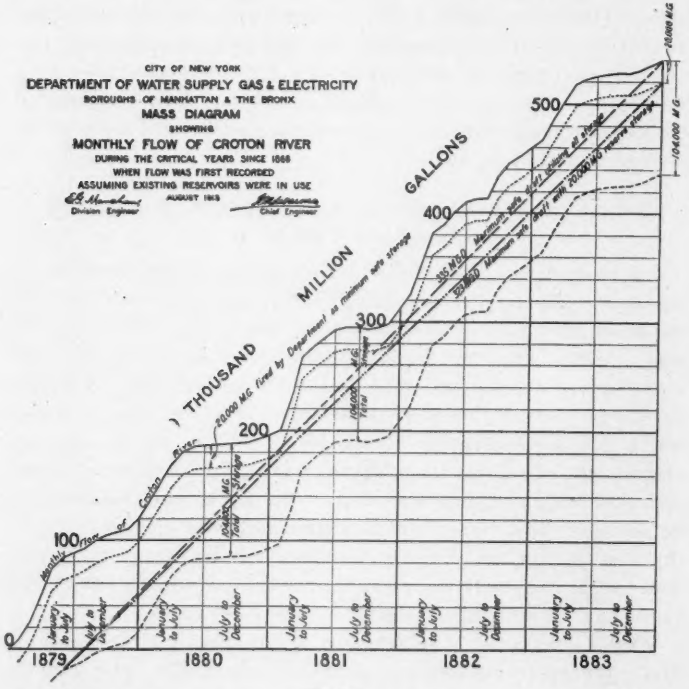


FIG. 1.

the low run-off years, and the two lines of maximum draft, one without any reserve in reservoirs and one with 20 000 million gallons reserve. The first rate is 335 m.g.d. and the second 323 m.g.d. The second is considered the safe rate of draft for New York in the light of the experience of the past three years.

Borough of Brooklyn.

While Brooklyn has for many years had little or no margin between the consumption and minimum safe supply from the system, there was no difficulty in meeting all requirements in 1911, when Manhattan and The Bronx were threatened with shortage of water. This was due mainly to a large increase in available supply from improvements in the condition of the wells, which furnish about one half of the supply, and to the reduction in consumption probably caused by general knowledge of the unusually dry season and consequent shortage of water in the Croton watershed and in many communities near New York City. The increase in consumption in the winter and spring of 1912 showed clearly that additional stations to draw from the subsurface waters of Long Island would be required unless the growth in consumption was curtailed; the consumption for the first six months being 149.1 m.g.d. as compared with a safe supply of 150 m.g.d. from the works as then developed.

Owing to the expected completion of the Catskill system in 1916 so that water could be delivered at that time to all boroughs, any new works would have a very short useful life, with consequent high cost per million gallons. On the basis of the cheapest type of station machinery and driven well system and without any allowance for conduit capacity or pumping equipment at the main station at Ridgewood, where all the water from the main watershed is pumped into the distribution reservoirs or mains, the cost delivered into the distribution system is as follows:

For water made available in 1913	$36 per mil. gal.
For water made available in 1914	42 per mil. gal.
For water made available in 1915	56 per mil. gal.

If the supply required were to be reduced so that existing sta-

TABLE 6.

BOROUGH OF BROOKLYN, AVERAGE DAILY CONSUMPTION, 1903 to MARCH, 1913, INCLUSIVE.

(Million gallons.)

Month.	1903.	1904.	1905.	1906.	1907.	1908.	1909.	1910.	1911.	1912.	1913.
January....	107.8	116.5	123.2	121.6	134.1	141.7	133.4	142.7	151.1	156.1	122.0
February...	108.6	128.2	129.5	128.7	139.8	148.8	134.4	149.7	148.9	159.1	128.9
March.....	105.1	114.5	123.6	126.1	134.8	138.7	134.1	142.8	147.5	148.6	122.6
April.....	103.0	106.6	117.8	126.3	134.0	134.4	133.5	136.3	141.0	144.0	118.6
May.....	104.8	106.5	121.5	129.5	136.6	133.8	130.3	137.2	138.4	143.8	119.3
June.....	100.7	109.0	120.3	134.3	139.0	144.7	137.2	139.1	138.5	143.1	127.6
July.....	105.2	108.4	118.3	126.3	139.1	145.7	141.3	147.6	145.5	144.2	....
August.....	102.0	110.3	114.7	130.0	135.0	143.9	142.0	143.7	138.9	136.1	....
September..	108.1	113.2	114.0	133.0	136.6	143.2	143.0	145.7	140.8	139.3	....
October....	103.7	112.7	115.3	124.7	134.6	142.6	138.5	143.6	132.6	136.5	....
November..	99.6	112.9	114.0	119.3	131.5	138.5	134.1	142.1	127.7	126.3	....
December...	108.5	119.5	119.1	125.5	132.8	132.0	136.2	146.7	133.2	126.7	....
Average..	104.7	113.1	119.2	127.1	135.6	140.6	136.5	143.1	140.3	142.0	123.2

tions could be shut down, the saving in maintenance and operation was estimated at about $24.00 per million gallons.

On the basis of the results obtained from water-waste prevention work in Manhattan and the Bronx, it was evident that such work in Brooklyn, if carried on along similar lines, would be financially advantageous. Work on detection of waste from leaks in mains and services had already been carried on along the waterfront; and owing to absence of rock and rock-filled streets in Brooklyn, there were practically no large leaks that would not show at the surface, other than along the waterfront. It was proposed, therefore, to limit the work in Brooklyn to the sending out of notices and to house-to-house inspection.

In June and July, 1912, 175 000 copies of the following notices were delivered at a cost of $1 137.50, which, together with the printing cost, made a total of $1 412.50.

IMPORTANT.

To the Owner of the Premises:

To stop waste of water, an inspection is to be made of these premises, and your attention is called to the necessity of having all fixtures in good order, as the rules of the department provide a penalty of two dollars ($2) for each leaky fixture. The fixtures which are ordinarily found out of order are tanks and toilets, faucets and ball-cocks controlling overflow of tanks.

You are hereby notified to have all leaky fixtures repaired immediately.

The use of hose, either inside or outside of buildings, is prohibited, unless a permit is obtained from the Department.

It is hoped that you will do everything in your power to stop all unnecessary use of water. Every gallon of water that is supplied to the Borough of Brooklyn has to be pumped twice, and some of it three times, so every gallon saved means a saving to the taxpayer.

Use what you need, but do not waste it.

Yours truly,

F. T. PARSONS,

Deputy Commissioner, Borough of Brooklyn.

The consumption showed a drop of 10 m.g.d., see Table 6, which it was estimated was due to the notice. Assuming, as in

TABLE 7.

BROOKLYN,—NUMBER OF MEN EMPLOYED, PREMISES EXAMINED, AND LEAKY FIXTURES FOUND DURING HOUSE-TO-HOUSE INSPECTION, JULY, 1912, TO JUNE, 1913.

Months.	Number of Inspectors. Average per Day.	Number of Clerks for Office Work. Average per Day.	Number of Premises Inspected.	Number of Leaks Found.	Number of Premises Re-examined.	Number of Fines Imposed for Failure to Repair Fixtures.	Amount of Fines Imposed.
1912.							
August	35	9	8 764	9 333	1 022	18	$36.00
September	35	8	12 289	16 650	6 483	781	1 562.00
October	35	8	15 064	21 861	5 788	383	766.00
November	35	7	13 225	14 512	7 762	585	1 170.00
December	35	7	11 783	17 134	8 253	442	884.00
1913.							
January	36	5	6 638	11 476	6 242	761	1 522.00
February	36	5	10 757	15 713	4 482	606	1 212.00
March	36	5	10 885	14 252	5 785	282	564.00
April	36	5	14 674	14 628	4 116	643	1 286.00
May	40	5	18 668	17 440	5 528	944	1 888.00
June	..	.	.....	.....	.....	169	338.00
Total	..	.	122 747	152 999	55 461	5 614	$11 228.00

Total cost of work to June 1, 1913, $37 074.68.

TABLE 8.

SAVING OF WATER SECURED BY HOUSE-TO-HOUSE INSPECTION IN BROOKLYN, AS INDICATED BY PITOMETER GAGINGS OF CONSUMPTION.

Districts.	Character.	Daily Consumption before Inspection. Gallons.	Daily Consumption after Inspection. Gallons.	Saving. Gallons.	Saving. Per Cent.
1, 2,	Mainly business and manufacturing	23 884 000	21 547 000	2 337 000	10
3 (x),	Manufacturing and shipping	13 000 000	.....	2 200 000	17
4, 5,	Mainly resident, medium-class	17 908 000	14 078 000	3 830 000	21
6, 7,	Partly residential and business	12 713 000	10 343 000	2 370 000	19
8,	Shipping and low-class tenements	9 250 000	7 750 000	1 500 000	16
9,	Shipping and low-class tenements	6 733 000	5 396 000	1 337 000	19
10,	Manufacturing and low-class dwellings	9 783 000	6 807 000	2 976 000	30
11,	Medium-class residential	9 610 000	7 110 000	2 500 000	26
12, 13 (x),	Medium-class residential	12 261 000	.....	3 065 000	25
17, 23 (x),	High and medium-class residential	10 049 000	.....	2 010 000	20
	Total	125 191 000	.....	24 125 000	19 Average

$$\text{Saving} \frac{24\,125\,000}{125\,191\,000} = 19 \text{ per cent.}$$

Cost of pitometer gagings	$7 200.00
Cost of inspectors, clerks, etc.	29 500.00
	$36 700.00

x Indicates districts in which the saving has been estimated.

Manhattan and The Bronx, that the effect of said notice was lost in two years, the cost was $0.40 per million gallons saved.

Thirty-five inspectors were placed on the house-to-house inspection work early in August, and eight clerks were required to handle the leaks reported. The detailed results of the work of these inspectors, which was continued up to June, 1913, are given in Tables 7 and 8.

It will be seen that the reduction in consumption amounting to 24 m.g.d. effected by the inspection of buildings was much greater proportionally in Brooklyn than in Manhattan and The Bronx, the minimum reduction being 10 per cent. and the maximum 30 per cent., with an average of 19 per cent. This was probably caused by the lesser effect of the printed notices to repair leaky faucets and the elimination of the question of shortage of water in the Brooklyn campaign. In the Brooklyn work there was also a longer period elapsing between the sending out of the notices and the inspection of buildings. The net cost of this work was $26 000, and assuming, as in Manhattan, that the waste stopped would all reappear in two years' time, the cost of saving the water was $3.00 per million gallons. The amount saved per inspector employed was equal to about three quarters of a million gallons daily, which was over three times the amount per inspector in Manhattan. This was due to the work being carried on with a smaller number of inspectors, and each inspector was therefore credited with a larger saving than in the Manhattan work. If comparison is made between Manhattan and Brooklyn on the basis of inspector days, assuming that the leakage stopped would reappear in two years' time, the result is as follows:

Manhattan,	11 600 inspector days, resulting in saving 7 800 m.g., equivalent to 670 000 gallons per inspector day.
Brooklyn,	9 400 inspector days, resulting in saving 8 800 m.g., equivalent to 940 000 gallons per inspector day.

The financial returns in Brooklyn were excellent, it being practicable, with a reduced consumption, to shut down six pumping stations and to use approximately 6 m.g.d. for the Borough of Queens, eliminating thereby an equivalent amount of water pur-

chased from a private company at a cost of $65 per million gallons. It is estimated that the reduction in maintenance and operating charges due to water-waste work is about $300 000 annually.

While the results of water-waste work have been excellent, from the viewpoint of the department, one must not lose sight of the inconvenience to the consumers from house-to-house inspection and the expense involved in the repairs to defective plumbing. It is not believed that the methods adopted should be used except where very favorable results are to be expected, or else where the need for saving water is urgent. Without universal metering, however, it is necessary to adopt temporary expedients for reducing waste and conserving the water supply resources, and these expedients, as applied in New York City, have certainly been most successful.

The house-to-house inspection work was carried on under the direction of the Bureau of Water Registrar, Mr. Benjamin A. Keiley being water registrar for Manhattan, and Mr. Wm. R. McGuire, water registrar for Brooklyn. The general planning and all water measurement work was under the Bureau of Water Supply, of which Mr. I. M. deVarona is chief engineer, the writer having charge of the maintenance and operation work of said bureau.

DISCUSSION.

Mr. Edward S. Cole.* Some ten years ago the speaker had the privilege of conducting a similar investigation in New York City, which led to the introduction of the pitometer system described in the paper just read, and it is his conviction that 72 gal. per capita daily is twice as much water as the people of Manhattan and the Bronx actually use. This is based upon the well-known character of New York's population, which is overwhelmingly made up of tenement-house dwellers and small water users.

The meter records of Worcester, Mass., show that 10 or 12 gal. per capita covers the actual use of a great mass of that city's population, comprising low-cost homes of mill operatives, etc., and there are many data to prove the same thing. The actual per

* New York, N. Y.

capita requirements of Manhattan and The Bronx may be apportioned, according to the speaker's experience, as follows:

50 per cent	15 gal. daily.
20 per cent	20 gal. daily.
20 per cent	40 gal. daily.
10 per cent	100 gal. daily.

Or an average of about 30 gal. per capita — less than half the figure given by Mr. Brush in his paper as the domestic consumption of the city. From this it is reasonable to conclude that there is yet much to be done in the way of water-waste restriction in New York. Adding a fair amount for unpreventable waste, it should be possible to reduce the present per capita consumption of 72 gal. daily to 40 gal.

We should not forget that the reduction of a few gallons per capita in a great city like New York represents an enormous volume of water. For example, a saving of 30 gal. per capita for a population of 3 000 000 means 90 000 000 gal. per day, the value of which at such a time as the water shortage of 1912 in New York City is beyond calculation.

It was unfortunate that the pitometer tests of 1902 and 1903 were abruptly ended by a change of administration, for the work was only well begun. It is but reasonable to assume that, had our investigation continued, there would have been no such danger of water famine in 1911 and 1912. That the city narrowly escaped a serious water famine in those years is well understood. The rains came in the nick of time, and it would not be wise for any city to risk so grave a danger by so narrow a margin.

The lesson to be drawn from this experience is clearly that water waste in a great city cannot be stopped in a hurry. It takes time to locate underground leakage and losses, and after a system has been made comparatively tight and efficient, it will take constant supervision to maintain it so. In this country we need a system of district metering and supervision like that in use in London and other English cities. Such service is the more imperative in our larger cities, where the general introduction of meters is delayed.

MR. W. C. HAWLEY.* I have only one point in which I differ from the writer, and that is I cannot agree with him that there is

* Chief Engineer, Pennsylvania Water Company, Wilkinsburg, Pa.

no need for restricting leakage in plumbing. It is certainly not fair that "A," who puts a good class of plumbing into his building and maintains it in good shape, should be obliged to pay rates to help keep up a large plant because "B" does not put in a good class of plumbing and does not maintain it.

I have had some experience in this matter of hunting for water waste and stopping leaks, which perhaps may be of interest. In 1896, when I took charge of the plant at Atlantic City, the city was facing a water famine. In the previous August the pressure had been at times below 20 lb. per sq. in. The city was already inaugurating a general metering of all services, but there was not time to secure results in that way. We started at once a house-to-house inspection, and where leakage was found a report was made to the owner, with the threat that unless the leakage was stopped at once the premises would be metered. With the universal fear of a meter in an unmetered town we found that to be one of the most excellent arguments that we could advance: it certainly was better than a fine or threat of prosecution. The result was that in four or five months the consumption had been so reduced that we went through the following summer with an ample supply of water, and eighteen months from the time that we began we had reduced the consumption from an average of 250 to 260 gal. per day per capita to 50 or 60 gal.

At the plant with which I am now connected it became necessary to install a filter plant, and about five years ago we began work on the plant. At that time we were pumping about seven and a half million gallons per day, and there was no reason to anticipate a sudden increase in the demand. We planned therefore for a plant capable of filtering ten million gallons per day, with two extra filter tubs that could be equipped if needed, giving an immediate capacity of 12.5 m.g.d., with ultimate expansion to a capacity of 20 m.g.d. By the time the plant was completed in 1909 we found that we were pumping 10 m.g.d., and during that summer many days we were up to 11 m.g.d. We had no knowledge of where this increase was going. The following January we discovered a leak where a 4-in. cast-iron pipe had snapped square in two in the bed of an old run, and about a million gallons per day was going to waste there. Three months later

we found a very bad lead joint where a wrought-iron pipe had been leaded into the bell of a cast-iron pipe under a seventeen-foot fill, and another million gallons a day was going to waste there. I came to the conclusion that we should have some way of finding such leaks, so we invested in a pitometer and detectaphone and began a systematic hunt over our system of some one hundred and fifty miles of pipe. The results have been most satisfactory; we have reduced our pumpage materially.

I have some figures which I think would be of interest. For the year ending April 1, 1913, we pumped a total of four hundred and nine and a quarter million cubic feet in round numbers. Of this we accounted for 54 per cent. in industrial consumption; 23.1 per cent. in domestic consumption; and including sewer flush tanks, the free list to municipal buildings and schools, water used by the company in its own office buildings and for meter testing, for the boilers at the pumping stations, the stoker motors, the water used in washing at the filter plant, and that wasted in cleaning the sedimentation basins, we accounted for a total of 79.8 per cent. of the water pumped. With pump slip estimated at 2 per cent. (which of course is low, but our pumps are Riedler pumps and the amount pumped is checked day by day by Venturi meters), that gives us a total of 81.8 per cent., not making any allowance for water used for street washing, sewer flushing, or street sprinkling. And there is practically no estimating as to any of the quantities. It is interesting to note that the domestic consumption averages 24.3 gal. per person per day; our industrial consumption is unusually large, 56.7 gal. per day, so that our total consumption per capita is 105 gal. per day including the 19.1 gal. not accounted for.

It seems to me that while hunting for leaks is absolutely necessary, the prevention of leaks is equally or even more important. "An ounce of prevention is worth a pound of cure." I have found that at least two of the methods which we have adopted have proved very successful. At Atlantic City the leakage was not to any extent from the mains or from the service lines; the leaks were almost altogether in the plumbing, and the meters induced the owners to make repairs. The pressure was low, about 40 lb. normal pressure. In our plant at the present time, while we have

pressures up to 210 lb., a large part of our district is under from 100 to 170 lb. pressure, and a considerable part of our leakage is from the mains and from service lines which are lead pipe, as the soil is destructive of iron pipe. Some years ago we adopted the use of a patented coupling instead of the ordinary wiped joint. We have put in a great many of these couplings and we have not had a single case of leakage from them, except where the pipe has been disturbed. I found that fifteen or sixteen years ago a considerable number of one of the earlier forms of patented couplings were put in in one of the old plants which were purchased by our company, and of those couplings not one has given us trouble in the past eight or ten years except where it has been disturbed by some excavation. I believe that the elimination of the wiped joint has made a very material difference in the amount of leakage; and we are eliminating them just as fast as we can.

For some years past we have been using leadite for joints in our mains, and I believe that we have solved another difficulty. We have not had a leak at any of our leadite joints (except one, and that was not important), and we have not had a joint blow out. We find in addition that it has a very high resistance to the flow of electricity, and our mains are being protected from electrolysis.

I think that these are things that are equally as important as hunting for leaks, and will give results that are well worth all that they cost.

Mr. Brush. From what Mr. Hawley has just said, it seems as if I must have given a somewhat erroneous impression as to the attitude of New York City towards leakage. It is not and was not the idea in the water department of New York City that it is not important or necessary to stop existing leaks either in mains or in plumbing inside the buildings or to prevent leaks occurring in the future. As far as leaks in the mains are concerned, we have a permanent force of about fifteen men which is used for detection of leakage in the mains and services; that is, outside of the buildings.

The point that I intended to make was that with a gravity system of a capacity greater than the demand from a financial viewpoint it does not pay to go after the house leakage in a systematic way when your cost of stopping that leakage is greater than the

cost of new trunk mains, which is the only expense involved as long as your supply is greater than the demand. Even the cost for new trunk mains has been eliminated at the present time, due to the unusual large reduction in consumption. In other words, our trunk main capacity is now greater than would be really needed for the city of New York with its present consumption, as far as Manhattan and The Bronx are concerned.

At the present time metering is not a matter which is being actively discussed in New York City, because the authorities are not in favor of it; and it is doubtful whether to-day it is financially advisable. But as far as stopping leaks in the system itself is concerned, that is, in the mains and in the services outside of the houses, we believe that as a matter of efficient administration we ought to take the steps necessary to eliminate such leakage. And our experience has been that that leakage comes in the rock-filled streets.

I had charge of the removal of about thirty miles of mains in the borough of Brooklyn, where we replaced the old mains with new ones. Those mains were laid with lead joints and I think that twenty-five joints in the thirty miles would cover those that leaked. None of the joints leaked so as more than to drip, or at most to run a stream which was less than the size of a pencil. Of course a good many places do not have as good joints as Brooklyn, but the above was the experience with mains laid in Brooklyn back in '58 and '59 and removed in the period beginning with 1902.

As far as stopping leaks in the houses is concerned, we believe that in New York it should only be taken up where the financial returns are at the present time considerably greater than the cost of such work, because it is objected to by the majority of the people and is not necessary on the question of a sufficiency of the supply. We certainly believe thoroughly in going after leaks outside of the buildings, and also in going after leaks in the buildings where it is financially advisable to do so.

As I previously said, metering to-day is not a really practical question for discussion in New York; but the time will come in the not very distant future when the general metering of services will be a very important question and one that will then undoubtedly be taken up actively.

MR. JOHN C. WHITNEY. I would like to ask Mr. Brush whether he does not consider it very likely that there would be an increase in the waste of water from leaks where new systems are installed in the large buildings in New York City.

MR. BRUSH. We do not anticipate any large increase in the number of leaks from that cause. We do anticipate a considerable increase in the amount of water lost through leakage, and it has been the practice in the borough of Brooklyn since 1905 to reduce that loss by a reduction in pressure during the night hours. That is, we keep the pressure during the evening and midnight and early morning hours down to, and slightly below, the pressure during the day time, by controlling the flow at the reservoir. That can be done in a large city with perfect safety, because the draft for fire purposes is small unless the fire becomes a large one, in which case the gates are open at the second alarm. There has been no difficulty in the last eight years of controlling the system that way.

There will certainly be a material increase in the amount of water lost in New York City with increased pressure, and there will be an increased pressure with the introduction of Catskill water. We have pressures as low as 20 lb. covering large areas, and such a pressure is of course unreasonable. Every city in the United States should have a pressure that will carry water to the upper floor of buildings that can be normally economically constructed in the district in question. In other words, we should supply New York City with pressure that would certainly carry water to the top of a building six to eight stories in height, which is the normal height of buildings erected on New York City land.

The question of stopping the leakage in the buildings in New York City is a different problem from that which the majority of cities have to face, due to the large amount of water that is introduced into New York City whenever any new works are constructed. When we consider that it will be eight or ten years before the question of adequate supply will come up, the problem is presented in a different light from that in which it is usually presented. The amount of money involved in stopping leakage is not one of thousands, but it runs up into hundreds of thousands.

I agree with Mr. Cole that our per capita consumption is far beyond what is necessary, but just how far beyond I am not in a position to state. In the next five years most of us will be in a much better position to settle that question in New York City and other cities than we are to-day, because every year adds to our knowledge of what is the proper per capita consumption. In New York an average consumption of around 30 gal. per person is about what is necessary for the ordinary domestic uses in families living in moderate circumstances. Of course when you get into tenements you come down to a much smaller per capita consumption, and there it might run down as low as 15 or 20 gal.

MR. BEEKMAN C. LITTLE. Mr. President, I should like to ask Mr. Brush if he included in his house-to-house inspection those houses and buildings that were metered. And if so, I wonder if he made any computation of what percentage of the total leakage was found in the houses and buildings that were metered.

MR. BRUSH. We did not include the metered premises except by sending printed notices to such premises. We assumed that there was leakage on metered services, but we concluded that with a greater number of unmetered premises than we could inspect we would confine our attention to them. We did not therefore inspect the metered premises.

MR. EDWARD D. ELDREDGE. Mr. President, I would like to ask Mr. Brush if he would consider it advisable for the purpose of preventing leaks that services laid on private land as well as on the public highway should be under the control or supervision of the water department.

MR. BRUSH. My personal opinion is that they should be, and furthermore that they should be installed by the department. We have our inspectors who cover the services up to the building; inside the building the department has nothing to do with the plumbing, but under our laws we are not permitted to install services. We install the taps, as they are put in entirely by the city tappers; but we have no control, other than inspection control, over the services to the building. I think that the city should have better control of the plumbing fixtures in the building. That question covers a big field and better plumbing will only come as the property owners realize that it pays to put in good plumbing

rather than to allow speculative builders to put in cheap plumbing because eventually the community has to pay the bill for both defective plumbing and leakage and waste of the water supply.

MR. JOHN S. ELY (*by letter*).* The present systematic attempt to reduce waste in Philadelphia was begun in April, 1912, by starting a thorough house-to-house inspection for leaking fixtures. Pitometer surveys were begun in August, 1912. The work during the first year was confined almost entirely to West Philadelphia.

For convenience in house-to-house inspection, the city was divided into twelve sections, lettered A, B, C, etc., and the blocks in each section were numbered consecutively. Fifty men were employed, at $2.00 per day, with an experienced district inspector as foreman, who laid out the work for his men each morning, assigning a certain block to each man. These inspectors found a great many leaks, and the results of their inspection began to be apparent immediately in reduced pumpage.

The corps has since been weeded out and reduced to thirty, the pay increased to $2.50 per day, and the men provided with aquaphones and taught how to use them. These aquaphones are inv uable in locating leaks in underground service and yard hydrant pipes. By their use about 1 500 such leaking underground pipes have been found.

The aquaphones are also valuable in expediting the work of inspection, for the inspector, by listening on a single spigot, can tell at once whether any water is running in the house, and if there is none, can proceed to the next house, thus saving the time and the inconvenience to the householder of a complete inspection.

The men wear badges and carry cards for identification, and the following general instructions are issued to them:

1. Inspectors must wear their badges on the outside of their coats in plain sight.
2. They must at all times be polite and courteous in their manner, and must cause householders as little inconvenience as possible.
3. They must ask permission of the householder before entering private rooms or bathrooms, and avoid doing anything which might be misconstrued on the part of the householder.
4. They will not waste time over small and trivial leaks. In leaks smaller than $\frac{1}{4}$-in. stream, it is sufficient to call the tenant's

* Assistant Engineer in Charge of Water Waste Prevention in Philadelphia.

attention to them, and no written notice to repair need be made out. It is of much more importance to spend the time in finding large leaks.

5. They will in all cases carefully examine the service pipe from the street, using an aquaphone, and in cases where there seems to be a leak in the service, it shall be followed up until located and shall be reported to the foreman at the first opportunity.

6. In cases where leaks are found of ¼-in. stream or more, the regular printed notice to repair will be carefully made out and left with the tenant, the duplicate copy being kept and given later to the foreman.

7. Inspectors will spend only enough time in each house to walk rapidly through and note the condition of plumbing. Five or ten minutes should be sufficient in all cases.

8. In cases where leaks of ¼-in. or more are found in rented houses, the name and address of the owner or agent should be taken and written on the duplicate slip.

9. Inspectors shall keep steadily at work during the whole day and endeavor to find as many *large* leaks as possible. The city pays you for your time and is entitled to it.

10. As inspectors are intrusted with discretionary duties, they will be required to display good judgment on all occasions, and lapses from a high standard of conduct will be dealt with accordingly.

A second inspection of those houses where notice to repair has been left is made about one week later. If the leak is still unrepaired, at the second inspection, a " shut-off " man is sent in a few days, and, finding the leak still not repaired, he shuts off the water at the curb.

Two clerks keep the records of the inspections and lay out the work for the second inspections and " shut-off " men.

The work of this corps is best shown by a summary of the first six months of 1913, as follows:

Number of buildings inspected	113 808	
Number of buildings showing waste	20 780	(18 per cent.)
Number of buildings repaired	17 371	
Number of buildings shut off	2 121	(Many vacant)
Fixtures repaired, toilet flush tanks	12 432	
Fixtures repaired, spigots	6 663	
Fixtures repaired, yard hydrants	1 286	
Fixtures repaired, horse troughs	36	
Fixtures repaired, service and hydrant pipes	2 367	

	Cost.	Cost per Building Inspected.
Labor	$7 908.21	$0.0695
Material	100.40	
Transportation	189.10	
Total	$8 197.71	$0.072

The ordinary flush tank of cheap make is responsible for a very large percentage of the total waste. It is often concealed and a good-sized flow may run constantly with very little sound.

In August, 1912, the bureau purchased six Simplex pitometer sets, including recorders. The recorders are of a recently perfected type, giving a twenty-four-hour record of the velocity of flow in red ink on a circular chart, driven by clockwork. They were first used to check the output from the various pumping stations and filter plants. They are now being used to measure the consumption in various districts of the city, a district being isolated in the usual manner by lines of closed valves and the flow into it measured on one or more large feed mains.

In addition, a number of pitometer rods were purchased for use with a U-tube in making night block surveys. For this purpose the apparatus is set up in a shelter box over a tap in the street main at some convenient point. The adjacent territory is then cut in, a block at a time, by closing the valve at one end and feeding past the pitometer. An observer notes the deflections in the U-tube and the time of each deflection. Thus, the night rate of flow into each block is obtained (the work always being done between 11 P.M. and 5 A.M.). A report of these rates is turned in the following morning and house-to-house inspectors are sent through all the blocks which show a high rate until it is satisfactorily accounted for.

In the six square miles of territory examined in this way, only two leaks have been found in the street mains, these being small joint leaks. In all other cases, the leakage has been accounted for in broken service pipes or house plumbing.

A recent improvement in the method of making these night surveys has been made in the following manner. A short section of 6-in. flange pipe has been mounted on a light covered wagon, the pipe having 3-inch hose connections at either end, and a 1-in.

ferrule or pitometer connection in the center. The U-tube is fastened up on the inside of the wagon cover. The block to be examined is shut off at each end, and fed through a fire hydrant from another hydrant on a live block, the wagon being of course stationed between the two hydrants, thus measuring any leakage there may exist in the block.

This method has the following advantages:

1. It permits quicker work because there are fewer valves to handle. The average number of blocks covered in one night is about 20 with the wagon and 15 by the old method.

2. It is cheaper and does away with the necessity of tapping the main for a pitometer connection.

3. It can much more readily be taken to any part of the city, where surveys are desired.

It has the disadvantages of being less accurate in measuring the amount of leakage, giving rates about 30 per cent. less than the old method, due probably to loss of pressure in passing through the hose. An exact value of the leakage is not, however, necessary in rapid surveys of this character.

These surveys, when followed up by a thorough and efficient corps of house-to-house inspectors, are probably the quickest method of reducing waste in any given territory. It is not necessary for the pitometer corps to stop and examine each house and service individually, but only to find the block night rate. Likewise, it is not necessary for the corps of inspectors to examine those blocks where there has been shown to be no leakage. Each corps, therefore, reduces the work of the other. If at the same time, the district in which the work is being done is isolated and the flow into it being measured by recorders, the results of the work can be readily followed. The effects of this work are soon felt in the neighborhood in which it is being done in increased pressures.

The net result of the work done so far has been to reduce the rate of consumption in West Philadelphia from 145 gal. to 125 gal. per capita per day, or about 14 per cent.

The total pumpage for the whole city in May, June, and July, 1913, averaged 301.638 m.g.d., while for the same three months in 1912 it averaged 315.9 m.g.d., a saving of 4½ per cent., although only about one tenth of the area has yet been covered.

MR. CLEMENS HERSCHEL* (*by letter*). Nigh two thousand years ago it was written (" De Arte Poetica," 359): " Indignor, quandoque bonus dormitat Homerus " — I become indignant when the excellent Homer occasionally nods (is careless in his statements).

That represents my feelings exactly, on reading in your paper on Water Waste Prevention Work what you say at the top of p. 420.

" With a gravity supply . . . and with ample aqueduct and reservoir capacity, there is practically no difference in cost when very little water is being drawn [for use and waste] and when a full supply [and waste] is being drawn from the watersheds — . . . cost is not affected by reduction in water waste."

This is one of those insidious and dangerous half truths, amounting to heresy, that has cost the towns and cities of the United States untold millions of dollars during the past fifty years. For you will readily see — no one quicker than yourself, on having your attention called to it — that such doctrine engenders and fixes on a community and its officials habits of waste; and these in turn make necessary " extending the water works " many years before such costly procedures would otherwise have become necessary. Indeed, I know of a case where " extending the water works " was imminent, while utilizing the waste would have presumably sufficed for that city some forty or fifty years.

MR. BRUSH (*by letter*). Mr. Herschel criticises the proposition that, where the water works of a community have a capacity greater than the present needs of the community, there is no difference in cost if the amount of water drawn is in excess of the needs of said community, provided the draft is within the capacity of the works and the operating and maintenance charges are not increased.

This is the condition at the present time in the boroughs of Manhattan and The Bronx; and, as stated in the paper, the " cost," or the annual expenditure for maintenance and operation, is not affected by the amount of water now drawn from the watersheds, as the draft is well within the capacity of all parts of the system. There was no intention on the part of the writer to minimize in any way the importance, as a general proposition, of

* Civil and Hydraulic Engineer, New York City.

reducing waste of water. There are periods when, due to a combination of circumstances, the cost of reducing waste is greater than the cost of permitting it to continue, and under such conditions the writer believes that the engineer who recommends postponing water-waste prevention work is performing his duty, but he would be negligent if he failed to give ample notice to the responsible officials when there was necessity for undertaking water-waste prevention work, to avoid extending the water supply system.

The closing paragraph of the section covering "Water-Waste Work in the Future" shows clearly the writer's belief that, in the future, water-waste prevention work in New York City will again become a most important and vital financial question, and is now important as far as it relates to leakage from mains and services.

DECARBONATION AS A MEANS OF REMOVING THE CORROSIVE PROPERTIES OF PUBLIC WATER SUPPLIES.*

BY GEORGE C. WHIPPLE, OF HAZEN & WHIPPLE, CONSULTING ENGINEERS, NEW YORK CITY; PROFESSOR OF SANITARY ENGINEERING IN HARVARD UNIVERSITY.

DISCUSSION (*continued from page 227*).

[*September 11, 1913.*]

MR. L. B. LITCH.† Free CO_2 and the corrosion of iron pipes, producing the so-called "red water plague," are closely associated. Filtered waters in general, and particularly those which have been treated with sulphate of alumina or sulphate of iron, have been shown to be more corrosive than unfiltered waters. Extra precautions should be taken to prevent, if possible, this increase in corrosive action.

At the suggestion of Professor Whipple, experiments were conducted at the Steelton filtration plant; and as a result of these experiments new operating and controlling features were added to its regular routine. The Steelton filtration plant is best described in "The Purification of the Water Supply of Steelton," by James H. Fuertes.‡

The raw water supply of Steelton is from the Susquehanna River. Above the filtration plant this river has four tributaries. The north and west branches unite to form the main Susquehanna River at a point 60 miles above Steelton. The Juniata and Conedogwinet Creek flow into the main river at a point 16 miles above Steelton. The north branch drains the hard coal regions of Pennsylvania; the west branch, the sandstone and shale; the Juniata, limestone and red sandstone; and the Conedogwinet Creek, a limestone region. The drainage areas of these different tributaries are semi-mountainous and the streams are, therefore,

* This paper was published in JOURNAL N. E. W. W. A., Vol. 27, p. 193.

† Steelton, Pa.

‡ Trans. Am. Soc. C. E., Vol. 66, p. 135.

more or less " flashy." The chemical characteristics of the waters of these different streams, as well as their appearance, differentiate them sharply from one another.

The temporary hardness of the water from the north branch is very low; the permanent hardness very high. The color of the turbidity is black or grayish-black, but the suspended particles are partially coagulated, although the water is not clear between the flocs. The temporary and permanent hardnesses of the water from the west branch are low, the color of the turbidity is gray, and the suspended matter is so well-coagulated in very small flocs that the water is often clear enough between flocs to be filtered without the use of additional coagulant. The temporary hardness of the Juniata River and the Conedogwinet Creek are very high; the permanent hardnesses very low. The color of the turbidity of the Juniata River is red in its lower and yellow in its upper reaches. The color of the turbidity of the Conedogwinet Creek is yellow. The waters of these two last tributaries are clay bearing and the turbidities are typical of such waters.

The alkalinity of the Susquehanna River water at Steelton varies from 2 to 68 parts per million; the free CO_2 from 2 to 8 parts per million.

During ordinary stages of the river, the waters from the different tributaries do not mix in the main river but flow past Steelton in streaks so distinct that the four colors of turbidity may be noticed at one time. At such times there is very little mixing of these different waters. However, when a heavy rainfall occurs on any one drainage area, the whole river at Steelton predicts the character of the stream draining it. When the rainfall is general the characteristics of the individual tributaries appear in the Susquehanna at Steelton in a regular sequence, dependent upon the distance from Steelton to the points where the various branches empty into the main river.

Naturally the river frequently shows the effect of transition from one type of water to another. For example, there is the so-called " switch " water. This is a mixture of yellow or red water with the black water. It appears after the crest of the black water flood has passed. This " switch " water cannot be coagulated by alum alone, despite the fact that the alkalinity ranges

from 35 to 45 parts per million. This phenomenon has been observed at other points on the Susquehanna River. Soda ash is not effective to assist coagulation, but lime can be used with satisfactory results, the treated water being well coagulated and clear between the flocs. Frequently there is no reduction in the alkalinity of this water after alum has been added. The raw water after boiling is frequently acid to phenolphthalein.

Because of the varying character of the raw water described above, and also because of a very short reaction period (twenty-eight minutes) previous to passing the water to the roughing filters, it was imperative that the peculiarities of each class of water be studied in order that a satisfactory coagulant might be obtained when chemical treatment was necessary. In order to study the peculiarities of these waters, a 10-meter Kohlrausch bridge and apparatus for measuring the electro-conductivity of the water was added to the laboratory equipment. By means of this apparatus, chemical reactions, which are so slight that they cannot be measured accurately by the titration methods of ordinary chemical analysis, may be accurately recorded. Furthermore, reactions may be studied experimentally and during their whole course without removing any of the solution experimented with, thereby keeping the experimental volumes constant.

In treating the "switch" water with alum, an increase in conductivity is noted. The amount of this increase remains practically constant, thus indicating either that no aluminium hydrate is being formed, or the formation of a soluble salt. When this water was tested for free CO_2 after the addition of alum, a slight increase in the amount of CO_2 was noted, but only to the extent of about 25 per cent. of the amount called for theoretically by the addition of any given amount of alum. The corrosive action on iron of this treated water is greater than that of the untreated water, but it can be reduced greatly by the addition of lime. Lime, however, is never added in excess; its addition is controlled by the conductivity method mentioned above.

The corrosive effect of CO_2 is greater when the alkalinity is low than when it is high. Again, the increase in free CO_2 resulting from the addition of lime to a water of low alkalinity tends to arrest, or at least retard, the complete reaction between the alum

(aluminium sulphate) and the alkalinity (calcium and magnesium bicarbonates). Under this condition, it has been shown that there is an aluminium compound remaining in solution. This condition should be avoided in plants using alum as a coagulant. It is the practice at Steelton to consider CO_2 under the varying conditions of its occurrence, and to apply the proper corrective treatment for it when necessary. As a result of this treatment, the borough prides itself upon the small amount of red water trouble which has occurred.

When applying coagulant, under ordinary conditions, to any one of the typical waters described above, the residual alkalinity is never allowed to go below 10 or 12 parts per million, and when coagulating a raw water which is changing in character rapidly, lime enough to combine with the amount of CO_2 equivalent to the amount of alum added is always used, thus insuring the practical completion of the reaction in accordance with chemical theory and preventing the formation of any compound of aluminium other than the hydrate.

More study should be made of the reaction between alum and the water which is treated. Filter plant chemists and superintendents have been too much inclined to place reliance upon the theoretical reaction between alum and alkalinity given in the text-books, as explaining the reaction which takes place in practice, where the theoretical action never takes place because interfering chemicals are never absent. It is the writer's belief that the subject should be approached from the standpoint of physical chemistry, and because the reactions are taking place in extremely dilute solutions, the laws of mass action should be regarded with due consideration.

Mr. Edward D. Eldredge.* I have had an experience in Massachusetts which in some features is unique, and to which Professor Whipple's paper particularly applies. Our supply ranks with one other in having the least color, and in the scale of hardness it ranks zero, — the only one in the state of Massachusetts having that rank. The result is that during certain periods of the year, notably in the spring, there is considerable trouble from red water. The supply is obtained from a woodland

* Superintendent Onset Water Company, Onset, Mass.

pond fed by springs, and having no stream flow in or out. The watershed is entirely wooded with oaks and pines, and the soil is sandy. During the spring, when the level of the pond is rising, there seems to be present a considerable amount of carbonic acid, presumably taken from the decomposing vegetable matter on the surface of the watershed. Some seasons the amount of carbonic acid is greater than others, notably the year 1911, when in April there were three snowstorms which covered the surface like a wet sponge. The absorption of carbonic acid at that time seemed to be greater than in any other period that we have noticed. In 1912 the rainfall was normal and there was not such a noticeable amount. This last spring, 1913, the rainfall was quite excessive in April, and we noticed similar trouble with red water. As a result of Professor Whipple's paper last winter I made some experiments with calcium hydrate. I made a saturated solution of the hydrate and added it in small quantities to a sample of water in which were immersed pieces of iron and steel, to ascertain the action as a result of the addition of the hydrate. The action was very marked; a small quantity of calcium hydrate reduced the oxidation of the metal. It is my purpose, with the authority and advice of the State Board of Health, to adopt some method of introducing calcium hydrate, or some better chemical if possible, with the idea of reducing the red water plague during that particular season when the pond is receiving its new water. I presume the subject must be familiar in other localities where water is very soft.

For service pipes we have found that cement-lined gives the best results, the water having no action on the cement. With galvanized iron we have found a number of cases where the pipes had become so much corroded and filled with tubercles that they had to be removed.

JULIAN S. SIMSOHN, ESQ.* I note in Mr. Whipple's paper that he states carbonic acid gas can be as quickly and efficiently removed by soda ash as by lime. My experience has been that lime is somewhat superior, because the carbonic acid combines with it and can be removed in the filters as insoluble carbonate of lime. Soda ash, on the other hand, combines with carbonic acid to form bicarbonate of soda, a soluble product, which passes through the

* With the Electrolytic Purification Company, Philadelphia, Pa.

filters and into the supply. In hot water systems the bicarbonate of soda is decomposed, liberating carbonic acid, which is then at liberty to attack the piping. These thoughts are the result of experiments on both soda ash and lime, and in practice I have found the lime treatment to stand alone in producing a water entirely free from carbonic acid and its corrosive properties.

Mr. R. S. Weston* (*by letter*). At Reading, Mass., where there is a deferrization plant, the CO_2 is removed by the addition of lime, and the writer is informed that no corrosion of the pipes has occurred since lime was used.

In ordinary aëration by spraying downwards from perforated plates or sprinklers, it does not pay to provide for a fall of more than one meter, or 40 in. To obtain a better removal of carbon dioxide without the addition of chemicals, it is essential to expose the water in a thin layer to the action of the air. The action of the air always displaces the carbon dioxide, — at first rapidly, and then slowly, until equilibrium between the carbon dioxide in the atmosphere and that in the water is established. The rough surfaces in a bed of coke, brick, paving blocks, or in superimposed bundles of wooden slats greatly accelerate the washing out of carbon dioxide by the oxygen of the air. Dr. Dunbar, of Hamburg, has shown that if a coke bed, used for iron removal, be operated intermittently, it will absorb oxygen during the periods of rest, which oxygen will replace the carbon dioxide in the water during periods of operation.

At Reading, Mass., an aërator consisting of a bed of broken stone 3 ft. thick increased the oxygen in the water from 1.18 to 5.27 parts, and decreased the carbon dioxide from 20.0 to 7.2 parts per million.

At Rumford Falls, Me., the aërator used to treat the ground-water supply consisted of fifteen trays with perforated bottoms, placed one above another and spaced about 1.5 ft. apart. This apparatus reduced the carbon dioxide from 48 to 5 parts per million. By filling only two of the fifteen trays with broken stone, the carbon dioxide was further reduced to 3 parts per million, thus showing the results of contact.

* Consulting Sanitary Engineer, Boston, Mass.

At Middleboro the following results were obtained with a well water having a temperature of 11.6 ° cent.:

	Parts per Million.	
	Dissolved Oxygen.	Carbon Dioxide.
Well water,	3.3	48
Ditto, after dripping 1.5 ft. from a spray nozzle,	..	40
Ditto, after trickling over a depth of 4.5 ft. of coke and broken stone at a rate of 75 m.g.a.d.,	10.7	5.0
Ditto, after passing through a depth of 3 ft. of coke submerged in water, in a subsiding basin,	10.3	4.5

At Cohasset, Mass., the following results were obtained with a well water having a temperature of about 10° cent.:

	Parts per Million.	
	Dissolved Oxygen.	Carbon Dioxide.
Well water,	2.4	51
Ditto, after falling 3 ft. from the spray nozzle,	4.5	41
Ditto, after passing through a depth of 5 ft. of broken stone, all submerged, the rate of passage being equivalent to 75 m.g.a.d.,	5.75	29
Ditto, after falling 3 ft. from a spray nozzle and then trickling over a depth of 5 ft. of broken stone not submerged and operating at a rate of 75 m.g.a.d.,	10.5	7.7

At Brookline experiments are being conducted to determine the most efficient method of aërating the water, as follows:

System No. 1. Spraying from a nozzle from a height of 1.5 ft.

System No. 2. Spraying from a nozzle and then allowing the water to trickle over a layer of coke 2 ft. in depth at a rate of 75 m.g.a.d.

System No. 3. Like No. 2 but with a layer of coke 5 ft. in depth.

System No. 4. Like No. 2 but with a layer of coke 10 ft. in depth.

The following results are typical. The temperature of the water at the time of the experiments was 15.5° cent.

	Parts per Million.	
	Dissolved Oxygen.	Carbon Dioxide.
Wells,	2.02	24.8
Effluent, System No. 1,	8.49	8.5
" " No. 2,	8.90	5.5
" " No. 3.	9.55	5.2
" " No. 4,	9.63	4.8

The effect of aëration in contact varies with different waters, as well as with the relative temperatures of air and water and the intimacy of the contact between the same.

In order to increase hardness of water, it is often more convenient to spray water over broken limestone or marble than to apply to it the proper amount of calcium hydrate. The writer feels certain that it is always best to decarbonize the water to the practicable limit by aëration before beginning the addition of chemicals to reduce the corrosive effect of the water.

Prof. G. C. Whipple (*by letter*). There is one phase of the decarbonation question that was not mentioned in the original paper, namely, the effect which the addition of lime has upon the bacteria in water. Dr. A. C. Houston, of London, has shown by an interesting series of experiments that when water is treated with an excess of lime, such bacteria as those which cause typhoid fever are speedily destroyed. More recently, Mr. C. P. Hoover, the chemist-in-charge of the water filtration plant at Columbus, Ohio, has performed an even more important series of experiments, which indicate that typhoid fever bacilli die within a few hours in water from which the free carbonic acid has been removed. In other words, his experiments indicate that disinfection is obtained by the use of a smaller amount of lime than Dr. Houston contemplated using. Mr. Hoover's researches are published in the *Engineering Record* of September 6, 1913. This detailed account of the experiments is worthy of careful study. His conclusions were stated as follows:

(1) When enough lime is added to water to absorb the free and half-bound carbonic acid and to precipitate the magnesium content, the bacteria of the colon and typhoid group are killed in forty-eight hours after being so treated, provided the water does not contain large quantities of organic matter.

(2) The germicidal action is effective in from five to twenty-four hours when an excess of 1.2 to 1 gr. per gallon is added beyond that needed to reduce the temporary hardness to the lowest possible figure.

(3) Intestinal organisms will not live in water containing no free or half-bound carbonic acid.

(4) Lime-softened water inoculated with typhoid organisms or with crude sewage soon becomes free from them.

(5) The action is selective in that certain harmless bacteria grow, but the disease-producing germs do not.

It seems to the writer that if Mr. Hoover's experiments can be trusted, and they seem to have been made with the greatest care, we have here a partial explanation of the enhanced safety of water during storage in natural lakes and reservoirs.

It is a fact that has been established during recent years that algæ and other aquatic plants frequently use up all of the free carbonic acid during their growth by the biological process known as photo-synthesis. They will even remove some of the half-bound carbonic acid. It would appear, therefore, that this natural decarbonation of the water tends of itself to destroy such bacteria as the germs of typhoid fever.

Thus we see that natural storage tends to disinfect water even though the storage be short, provided that algæ are growing vigorously in the water. The term " purging," which is sometimes used to describe growths of algæ in ponds, is thus seen to have a meaning that is justified.

The title of Table 10, page 220, is slightly misleading. The figures given in the table do not show directly the reduction of carbonic acid, but rather the amounts of carbonic acid left after the stated periods of exposure.

The writer desires to thank those who have contributed to the discussion, and especially Dr. Thresh for his interesting account of English conditions. Mr. Simsohn states that he prefers lime to soda ash for the purpose of decarbonation, and with this idea the writer is in accord. Mr. Litch, of Steelton, has been carrying on a very valuable series of experiments on coagulation, and it is hoped that some day he will publish these in a more extended form so that the members of this Association may have the benefit of his work.

PROCEEDINGS.

The Thirty-Second Annual Convention.

Philadelphia, Pa., September 10, 11, 12, 1913.

The Thirty-Second Annual Convention of the New England Water Works Association was held at Philadelphia, Pa., September 10, 11, and 12, 1913.

The official headquarters of the Association were at Hotel Walton, where the sessions of the Convention were held and the Associate members displayed their exhibits.

The following named members and guests were in attendance:

Honorary Member.

Mr. F. W. Shepperd. — 1.

Members.

J. M. Anderson, M. N. Baker, L. M. Bancroft, F. A. Barbour, G. W. Batchelder, G. H. Benzenberg, C. R. Bettes, Philander Betts, F. E. Bisbee, A. E. Blackmer, J. W. Blackmer, Dexter Brackett, W. W. Brush, James Burnie, J. S. Buzby, J. M. Caird, T. J. Carmody, C. E. Chandler, E. W. Clarke, R. C. P. Coggeshall, E. S. Cole, F. L. Cole, W. R. Conard, H. R. Cooper, G. K. Crandall, A. W. Cuddeback, C. E. Davis, J. M. Diven, F. C. Dunlap, E. R. Dyer, J. H. Dunlap, E. D. Eldredge, G. R. Ellis, E. A. Fisher, A. D. Flinn, W. B. Fuller, W. E. Fuller, A. S. Glover, J. W. Graham, F. W. Green, F. H. Gregory, Patrick Gear, F. E. Hall, L. M. Hastings, E. L. Hatch, W. C. Hawley, Allen Hazen, A. B. Hill, N. S. Hill, Jr., W. C. Hopper, F. J. Hoxie, J. L. Hyde, D. D. Jackson, A. W. Jepson, G. A. Johnson, F. T. Kemble, G. G. Kennedy, Willard Kent, J. A. Kienle, F. C. Kimball, G. A. King, J. J. Kirkpatrick, Morris Knowles, E. B. Kontkovski, B. C. Little, J. B. Longley, F. H. Luce, T. J. Lynch, M. B. Litch, Daniel McDonald, T. H. McKenzie, W. A. McKenzie, John Mayo, F. E. Merrill, H. A. Miller, E. E. Minor, F. F. Moore, J. W. Moran, J. A. Newlands, F. L. Northrop, E. L. Nuebling, A. E. Pickup, W. D. Pollard, J. C. Rickards, W. H. C. Ramsey, J. F. Reagan, Jr., A. A. Reimer, P. R. Sanders, H. W. Sanderson, G. H. Shaw, J. E. Sheldon, R. W. Sherman, M. A. Sinclair, J. Waldo Smith, W. E. Spear, J. F. Sprenkel, G. A. Stacy, G. T. Staples, W. F. Sullivan, Russell Suter, R. J. Thomas, J. L. Tighe, J. A. Tilden, J. C. Trautwine, Jr., C. H. Tuttle, J. H. Walsh, F. P. Washburn, F. J. Wise, G. C. Whipple, J. C. Whitney, Logarus White, F. E. Winsor, I. S. Wood, Walter Wood, Timothy Woodruff. — 115.

ASSOCIATES.

American Bitumastic Enamels Company, by L. Stuart, L. B. Darling, G. J. Hermiston, J. Gibson, S. R. Rickards, and Harry Myers; Thomas D. Bausher; James Boyd & Bro., Inc., by Lewis Libengood; Buffalo Meter Company, by W. J. Chellew and R. L. Cook; Builders Iron Foundry, by N. L. Sammis; Central Foundry Company, by R. W. Conrow, K. G. Martin, H. J. Hoeltze, and W. H. Feltt; Chapman Valve Manufacturing Company, by J. T. Mulgrew; Eddy Valve Company, by F. S. Robinson; Electro Bleaching Gas Company, by E. D. Kingsley; *Engineering Record*, by A. E. Warner, R. K. Tomlin, Jr., and I. S. Holbrook; Gamon Meter Company, by C. A. Vaughan; Glauber Brass Manufacturing Company, by J. Bernstein; Joseph Dixon Crucible Company, by R. R. Belville; Hays Manufacturing Company, by C. E. Mueller; Hersey Manufacturing Company, by Albert S. Glover, J. A. Tilden, W. A. Hersey, W. C. Sherwood, W. T. Kershaw, O. P. Hanks, and B. D. Hutley; Lead Lined Iron Pipe Company, by J. W. McCormack and T. E. Dwyer; The Leadite Company, by J. G. McKay, George McKay, Jr., and J. P. McKay; Ludlow Valve Manufacturing Company, by A. R. Taylor; H. Mueller Manufacturing Company, by G. A. Caldwell, F. B. Mueller, and O. B. Mueller; National Meter Company, by E. E. Cooke, J. G. Lufkin, and W. P. Oliver; National Tube Company, by H. T. Miller; National Water Main Cleaning Company, by A. J. Yeager, B. B. Hodgman, and Clinton Inglee; Neptune Meter Company, by R. D. Wertz and T. D. Faulks; New York Continental Jewell Filtration Company, by E. K. Sorenson; Pittsburgh Meter Company, by V. E. Arnold, T. C. Clifford, and J. W. Turner; Rensselaer Valve Company, by F. S. Bates and C. L. Brown; Ross Valve Manufacturing Company, by William Ross; S. E. T. Valve and Hydrant Company, by C. L. Lincoln and E. I. Corcannon; Simplex Valve and Meter Company, by W. T. Harveson, E. R. Glenn, C. C. Belmey, A. C. Fisher, and M. M. Borden; A. P. Smith Manufacturing Company, by D. F. O'Brien, F. L. Northrop, T. F. Halpin, and A. C. Nieman; Standard Cast Iron Pipe and Foundry Company, by W. F. Dodds, W. C. Hammond, and W. F. Woodburn; Thomson Meter Company, by E. M. Shedd, W. S. Cetti, S. D. Higley, and J. L. Atwell; Union Water Meter Company, by L. P. Anderson and Edward Otis; Water Works Equipment Company, by W. H. Van Winkle, W. H. Van Winkle, Jr., and E. T. Scott; R. D. Wood & Co., by C. R. Wood, A. T. Prentice, H. M. Simons, and Walter Wood; Henry R. Worthington, by J. A. Post, Samuel Harrison, T. C. McBride, P. B. Fenlon, J. E. Torbush, C. H. Morse, C. F. Carver. — 91.

GUESTS.

Mrs. James Burnie, Miss Helen M. Burnie, Biddeford, Me.; Mrs. L. M. Bancroft, Reading, Mass.; Mrs. George T. Staples, Dedham, Mass.; Mrs. George A. Caldwell, W. J. Rose, W. R. Taylor, Mrs. Albert S. Glover, Mrs. Dexter Brackett, Miss Joan M. Ham, Boston, Mass.; Mrs. J. L. Hyde, Miss Helen Sanderson, Westfield, Mass.; Mrs. John Mayo, Bridgewater, Mass.;

Neddie Eldredge, Onset, Mass.; Mrs. George A. Stacy, Marlboro, Mass.; Mrs. Arthur E. Blackmer, Plymouth, Mass.; Mrs. Frank E. Merrill, Somerville, Mass.; Mrs. L. M. Hastings, Cambridge, Mass.; Mrs. Thomas J. Carmody, Joseph Lynch, Holyoke, Mass.; John E. Sullivan, Lowell, Mass.; Mrs. Irving S. Wood and D. K. Bartlett, Providence, R. I.; Mrs. Willard Kent, Narragansett Pier, R. I.; Mrs. George K. Crandall, New London, Conn.; Mrs. Charles E. Chandler, Norwich, Conn.; Mr. H. R. Cooper, Thompsonville, Conn.; Mrs. T. H. McKenzie, Hartford, Conn.; S. W. Hume, F. M. Griswold, James H. Van Burke, Mrs. John H. Gregory, Mrs. F. W. Shepperd, Fred Shepperd, Nathan C. Rockwood, Mrs. W. W. Brush, Fred W. Schultz, Mrs. I. S. Holbrook, Dr. George Ornstein, M. F. Tiernan, New York City; Mrs. Frank E. Winsor, White Plains, N. Y.; Charles H. White, New York City; Mrs. Fred F. Moore, Hawthorne, N. Y.; Mrs. James M. Caird, Mrs. Fred S. Bates, Troy, N. Y.; D. C. Randall, Tupper Lake, N. Y.; Miss Celia Ryan, Ausable Forks, N. Y.; D. N. Durland, Far Rockaway, N. Y.; D. A. DeCrow, Buffalo, N. Y.; Mrs. T. F. Halpin, Newark, N. J.; Alvin Bugbee, Charles H. Speck, Wm. J. Stewart, Trenton, N. J.; Mrs. F. W. Green, Little Falls, N. J.; C. D. Mathews, Camden, N. J.; B. F. Souder, Atlantic City, N. J.; Henry Ryan, Bridgeton, N. J.; J. W. Griffin, Jersey City, N. J.; Mrs. F. C. Kimball, Summit, N. J.; Mrs. G. G. Kennedy, Harrisburg, Pa.; J. Benbaker, Jenkintown, Pa.; George H. Wobensmith, C. A. Vance, Joseph Thompson, Julian S. Lincoln, Miss Longstreth, N. M. Akimoff, Mrs. George E. Nichols, Mrs. John C. Trautwine, Jr., H. W. Benjamin, C. P. Landreth, Mrs. G. M. Costello, George F. Noer, George M. Costello, Graham Starr, F. C. Viguerie, W. Whitby, Arthur C. Merrill, H. S. Purdy, Joseph Fenerty, Francis D. West, John Moody, Edward O'Brien, J. C. McHugh, C. N. Kaprie, Philadelphia, Pa.; M. K. Smith, Charles T. Martin, Wilmington, Del.; G. W. Young, Canton, N. C.; Miss May S. Pollard, J. F. Pollard, Pottsville, Pa.; Mrs. C. E. Mueller, Erie, Pa.; Mrs. M. B. Litch, Steelton, Pa.; Walter L. Watson, North Catasauqua, Pa.; Edward Elbert, Reading, Pa.; J. Archibald, Newtown, L. I.; Mrs. J. H. Dunlap, Iowa City, Ia. — 96.

Wednesday, September 10, Morning Session.

The convention was called to order at 10.30 A.M. by J. Waldo Smith, the President, who said:

When Director Cooke sent us a most cordial invitation to meet in convention in this city, we all expressed not only our willingness but our anxiety to come, for the fame of the chief executive of this city had gone abroad. We had heard that he was a man of great courage and great independence; that he was trying to give this city a practical business administration; and that to this he was appointing men to the principal positions in the city for merit

and fitness and not by reason of any political service, and that after these men had been appointed they were left to make good, — they were not trammeled in making their appointments or choosing their associates. This is a most unusual thing in a great city like Philadelphia.

It is with great pleasure that I introduce to you Mayor Blankenburg, of Philadelphia.

Hon. Rudolph Blankenburg. *Mr. Chairman and Members of the New England Water Works Association,* — I appreciate the very kindly introduction at the hands of your chairman. I am glad that the fame of this administration has reached outside of Philadelphia, because there are quite a number of people in Philadelphia who have not as yet heard of it. Perhaps it is because they don't want to hear. There are unfortunately too many people in this world who won't learn and who won't believe facts; but the facts are here.

As your presiding officer has said, it has been my aim to give Philadelphia a thorough business administration. That is the one thing needed in every municipality over our broad land. We must exclude politics in every way if we want to achieve and accomplish that kind of municipal government which will be of the greatest benefit to the masses of the people. This has been my aim, and I am glad to be able to look at two representatives of this administration who were appointed by me and through me and who are making good in every way. Let me assure you, gentlemen, that I have never yet asked a man's politics or his religion when I appointed him to office or was instrumental in having the appointment go to him, and I never shall. Efficiency is the watchword that has been the ground work of this administration.

I speak to you feelingly, gentlemen, because you are the oldest association in this country, — the New England Water Works Association. You have done a great deal of good, and you are not confined to-day, as I understand, to New England, but you embrace many parts of this country.

It is well that New England should come to Philadelphia, for in New England, in the city of Boston, — next to Philadelphia, of course, — we find more of the old spirit that was imbued and

that was implanted in our people during the War of Independence than in any other part of the country. People living in the far West cannot help it, because that was not part of our country then. But we will give you a Roland for your Oliver every time. You point with pride to Bunker Hill; we take you to Independence Hall. But we do not want to speak of this, because we are all one people, we are all united in one purpose, — to show to the world that the republican form of government can be established and maintained, and that it is not a failure.

Now, gentlemen, as mayor of this city I extend to you a most hearty welcome. We are really being favored, for the New England Water Works Association is with us to-day and the American Water Works Association will be with us next spring. There will be plenty of water to discuss. I don't know how it is with you, but sometimes here in Philadelphia we find a stick in the water. But we don't find any unfiltered water, any raw water. We are not giving you a raw welcome; we are giving you a welcome that is thoroughly filtered and clean, at least as far as the water is concerned.

I am not going to detain you by a lengthy speech. I believe Philadelphia is the first city in which water works were established, — by Benjamin Franklin. We often brag about Benjamin Franklin, and then the retort comes to us, " Oh, yes; but we gave him to you from New England." He wasn't a real Philadelphian, he was only imported — as I was myself. But Philadelphia had the first water works, and those old, old water works are still visible.

Make yourselves comfortable while you are in our city. The freedom of Philadelphia is extended to you most heartily. Have a good time, and I hope that you will remember your visit to Philadelphia in the future with the greatest of pleasure.

THE PRESIDENT. On behalf of the New England Water Works Association I thank you most heartily, Mr. Mayor, for this very cordial reception. I am sure that with all you have provided for us, and because of the historic interest of the city, our stay here will be most pleasant, agreeable, and instructive. And I hope that this meeting will prove of profit to you and your great city.

We have here with us Mayor Blankenburg's right-hand man,

Director Cooke, who presides, as I understand, over most of the departments of this city. We feel very cordial towards Mr. Cooke, because he saw fit to choose as his principal assistant in the water department a son of New England and a member of this Association. We would be very glad if Mr. Cooke would say a word to us.

MR. MORRIS L. COOKE.* *Mr. Chairman and Gentlemen,* — It is a great pleasure to say just a word. I am going to confine it simply to thanking the men in this room, as representing the engineering profession in this country, for the truly remarkable support that this administration has had at the hands of that profession. From every branch of engineering word has come to us, "We are at your service, and we are on call." Starting in as we did in many departments of the city administration without the most adequate engineering advice, it has been necessary on a great many occasions to go to the leading men in your profession, and in the engineering profession both in your branch and others. In every instance that appeal has not only not been in vain, but we have had a response and a character of assistance that would have made the engineering department of any administration a success.

As far as your stay here is concerned, I want to add my word to that of his honor the mayor in trusting that you will have a good time, and in begging that you will command my office if there is any way in which we can be of assistance.

The Secretary read the following names of applicants for membership, all of whom had been properly endorsed and approved by the Executive Committee:

Active: Weston E. Fuller, New York City; William John Turnbull, State Farm, Mass.; E. W. Sylvester, City Hall, Poughkeepsie, N. Y.; M. B. Litch, Steelton, Pa.; N. W. Akimoff, Philadelphia, Pa.; Eugene B. Kontkovski, St. Petersburg, Russia; Lazarus White, New York City; Wilbur Thomas Wilson, New York City; Frederick E. Tupper, City Hall, Quincy, Mass.; D. C. Shull, Apollo, Pa.; Walter P. Schwabe, Windsor Locks, Conn.; Jacob S. Langthorn, New York City; Arthur N. Burnie, Biddeford, Me.

* Director of the Department of Public Works, Philadelphia.

Associates: James Boyd & Bro., Inc., Philadelphia, Pa.; Buffalo Meter Company, Buffalo, N. Y.; Simplex Valve and Meter Company, Philadelphia, Pa.; American Bitumastic Enamels Company, New York City; The Leadite Company, Philadelphia, Pa.; Joseph Dixon Crucible Company, Jersey City, N. J.

On motion the Secretary was empowered to cast the ballot of the Association in favor of the candidates, and, he having done so, they were declared by the President duly elected members of the Association.

Mr. George A. King moved that the President be empowered to appoint a committee of five to nominate officers for 1914. The motion was adopted. The President subsequently appointed the following committee: Robert C. P. Coggeshall, chairman; George A. Stacy, Edwin C. Brooks, George C. Whipple, Charles W. Sherman.

The first paper on the program was on "Notes on Reduction of Waste of Water in New York City," by William W. Brush, deputy chief engineer, Department of Water Supply, Gas, and Electricity, New York City. The paper was discussed by Mr. Edward S. Cole, 220 Broadway, New York City; Mr. W. C. Hawley, chief engineer and general superintendent Pennsylvania Water Company, Wilkinsburg, Pa.; Mr. John S. Ely, assistant engineer in the Bureau of Water, Philadelphia; Mr. John C. Whitney, water commissioner, Newton, Mass.; Mr. Beekman C. Little, superintendent water works, Rochester, N. Y.; and Mr. Edward D. Eldredge, superintendent Onset Water Company, Onset, Mass.

Mr. A. W. Cuddeback, engineer and superintendent, Passaic Water Company, Paterson, N. J., read a paper entitled "Effect of the Condition of Meters on Revenue." This paper was discussed by Mr. Theodore H. McKenzie, secretary and treasurer Terryville (Conn.) Water Company, Southington, Conn.; Mr. John C. Whitney; Mr. William F. Sullivan, engineer and superintendent Pennichuck Water Works, Nashua, N. H.; Prof. Philander Betts, chief engineer Public Utilities Commission, State of New Jersey, Newark, N. J.; Mr. George A. King, superintendent water works, Taunton, Mass.; Mr. W. C. Hawley; Mr. Francis T. Kemble, secretary New Rochelle Water Company, New Rochelle, N. Y.; and Mr. John C. Trautwine, Jr., of Philadelphia.

Afternoon Session.

The President. The chairman of the committee on arrangements, Mr. Davis, has an announcement to make about the excursion to-morrow afternoon.

Mr. Davis announced that an excursion had been arranged by sight-seeing automobiles through portions of Fairmount Park, including stops at Queen Lane Pumping Station, Queen Lane Filters, and one of the high pressure fire stations, where a fire company would be called out and a demonstration given.

The first business of the afternoon was an illustrated paper by Mr. Hiram A. Miller, consulting engineer, of Boston, Mass., on "The Additional Water Supply for the City of Pittsfield, Mass."

The President. There are two matters laid over from the March meeting for discussion at this meeting. The first is the report of the Committee on Water Consumption and Statistics Relating Thereto, which was presented at the March meeting of the Association by Mr. Leonard Metcalf, the chairman. An opportunity is now afforded for further discussion of this report of the special committee on that subject. I would suggest that members who are interested in this subject will read carefully the very excellent report which was presented by this committee, and be prepared to take up the discussion of it at a winter meeting. This Association has always done very high-grade work in the reports of its committees, and it is desirable that this should be reviewed in the most thorough manner before it is finally adopted.

The report of the committee on "Low Yields of Catchment Areas in New England, and, at Their Discretion, Outside of New New England," comes up at this time. The chairman of that committee is not here, but I think some of the members of that committee are present. Discussion or remarks are invited. If there is no objection this report will also be laid over to a winter meeting.

Does any person present wish to suggest any further business to bring to the attention of this meeting at this time? There being no response a recess will be taken until eight o'clock this evening, when further papers will be presented.

EVENING SESSION.

THE PRESIDENT. In order that we may have a better understanding of the Philadelphia water works which we are to visit on Friday, Mr. Carleton E. Davis, the chairman of the committee on arrangements, and the chief engineer of the Bureau of Water of Philadelphia, will give an outline description of the Philadelphia water-works.

Mr. Davis then gave an illustrated talk on the Philadelphia water-works system.

Next came a paper by Mr. Francis D. West, chemist in charge, Torresdale Laboratory, on the "Torresdale Filter Plant Methods and Results from 1907 to Date," illustrated. The paper was discussed by Prof. George C. Whipple, of Harvard University; Mr. John H. Gregory, consulting engineer, New York City; Mr. Trautwine; Mr. Joseph S. V. Siddons, superintendent Torresdale Filters; and Mr. John A. Kienle, sanitary engineer, Electric Bleaching Gas Company, New York City.

A paper followed, on "Mortality Rates of Philadelphia in Relation to the Water Supply," by John A. Vogleson, chief of the Philadelphia Bureau of Health. As Mr. Vogleson was absent from the city his paper was read by Dr. Joseph S. Neff, of Philadelphia, Director of Public Health. At the conclusion of the paper it was discussed by Mr. John A. Kienle; Mr. Edgar M. Hoopes, Jr., chief engineer of the Water Department, Wilmington, Del.; Mr. Richard Winslow Sherman, chief engineer Conservation Commission, Albany, N. Y.; and Mr. W. C. Hawley.

THURSDAY, SEPTEMBER 11, MORNING SESSION.

The day's proceedings began with the reading of a paper by Mr. F. J. Hoxie, engineer and special inspector, Associated Factory Mutual Fire Insurance Companies, Boston, Mass., on "Methods of Locating Leaks in Water Mains." This was discussed by Mr. Allen Hazen, civil engineer, New York City; Mr. R. C. P. Coggeshall, superintendent water works, New Bedford, Mass.; Mr. Dexter Brackett, chief engineer Metropolitan Water Works, Boston, Mass.; Mr. George A. Stacy, superintendent water works, Marlboro, Mass.; Mr. W. C. Hawley; and Mr.

Patrick Gear, superintendent Holyoke Water Department, Holyoke, Mass.

A paper entitled "Loss of Head in Bends" was read by Mr. Weston E. Fuller, consulting engineer, New York City, and was discussed by Mr. Francis T. Kemble, Mr. Allen Hazen, and Mr. Richard Winslow Sherman.

Then came discussion of paper by Prof. George C. Whipple, on "Decarbonation of Water," which was presented at the March meeting of the Association. The President said that this was a subject that ought to appeal particularly to the men interested in filtration, and those troubled with the red water plague, and he called upon Mr. Whipple to open the discussion by saying more about his paper. It was also discussed by Mr. M. B. Litch, Steelton, Pa.; Mr. Edward D. Eldredge; and Mr. Julian S. Simsohn, electro-chemist, Electrolytic Purification Company, Philadelphia.

The President called for progress report from the committee on "Standard Specifications for Cast-Iron Pipe," Mr. F. A. McInnes chairman.

THE PRESIDENT. I think Mr. King has a report to make.

MR. KING. The committee has done some work, and can only report progress at this time. I have a letter here from Mr. McInnes, which I will read.

BOSTON, MASS., August 27, 1913.

WILLARD KENT, *Secretary,*
New England Water Works Association,
NARRAGANSETT PIER, R. I.

Dear Sir, — The committee on "Standard Form of Specifications for Cast-Iron Water Pipe and Special Castings" is not ready to report at the annual convention about to be held in Philadelphia. It is necessary to "Make haste slowly" in this matter, so many different interests being involved.

Yours very truly,
F. A. MCINNES, *Vice-President.*

THE PRESIDENT. There is also a progress report due on "Standard Specifications for Hydrants," Mr. H. A. Lacount, chairman. Is there any report on this subject? Does any one desire to say anything on the subject of "Standard Specifications for Hy-

drants "? There being no response I will call on Mr. Griswold to tell us about the standard hose couplings.

Mr. F. M. Griswold, general inspector, the Home Insurance Company, New York, then addressed the meeting in regard to the Standard hose coupling.

Mr. W. F. Woodburn presented the following report of the Committee on Exhibits.

PHILADELPHIA, September 11, 1913.

Mr. J. WALDO SMITH, *President New England Water Works Association:*

Dear Sir, — I take pleasure in submitting the report of the Committee on Exhibits.

The following Associate members exhibited:

H. Mueller Manufacturing Company, Decatur, Ill., brass goods, tapping machines, water meter tester, large pipe cutter, and other tools and appliances; A. P. Smith Manufacturing Company, East Orange, N. J., large and small tapping machines, fire hydrants, gates, brass goods and appliances; Hays Manufacturing Company, brass goods, tapping machines, curb boxes, etc.; Chapman Valve Manufacturing Company, Boston, Mass., brass and iron body gate valves, Anderson couplings, and fire hydrants; S. E. T. Valve and Hydrant Company, New York, gate and curb boxes; Lead Lined Iron Pipe Company, Wakefield, Mass., lead and tin lined pipe; Water Works Equipment Company, New York, tapping machines, automatic calking and tamping tools, etc.; National Tube Company, Pittsburg, Pa., black and galvanized pipe and special lead joints; Central Foundry Company, New York, Universal pipe; Ross Valve Manufacturing Company, high pressure fire hydrants, regulator valves, etc.; Simplex Valve and Meter Company, Philadelphia, Pa., meters and valves; Builders Iron Foundry Company, Providence, R. I., meters; Electro Bleaching Gas Company, New York, N. Y., water purifying apparatus; National Water Main Cleaning Company, New York, samples of filled and cleaned water mains; Standard Cast Iron Pipe and Foundry Company, Bristol, Pa., and Malden, Mass., cast iron pipe; American Bitumastic Enamel Company, Philadelphia and New York, preservative enamel; Joseph Dixon Crucible Company, Jersey City, N. J., graphite and preservative paint; The Leadite Company, Philadelphia, Pa., leadite and leadite gasolene furnace; T. D. Bausher, Reading, Pa., lead melting furnace and fuel; James Boyd & Bro., Inc., Philadelphia, Pa., pump valves and appliances; Hersey Manufacturing Company, South Boston, Mass., water meters; Neptune Meter Company, New York, N. Y., water meters; Henry R. Worthington, Boston, Mass., New York and Philadelphia, water meters; National Meter Company, New York and Boston, Mass., water meters; Thomson Meter Company, Brooklyn, N. Y., water meters; Union Water Meter Company, Worcester, Mass., water meters; Gamon Meter Company, Newark, N. J., water meters; Pittsburg Meter Company, East Pittsburg,

Pa., and New York, water meters; Buffalo Meter Company, Buffalo, N. Y., water meters; *Fire and Water Engineering; Engineering News; Engineering Record; American City.*

Submitted by
WM. F. WOODBURN, *Chairman,*
FRANK L. NORTHRUP,
THOMAS MCBRIDE,
Committee on Exhibits.

THE PRESIDENT. Is there any further business to be brought to the attention of this meeting at this time?

PROF. GEORGE C. WHIPPLE. *Mr. President,* — Last evening in the discussion of Mr. West's paper* I made a suggestion which I would like to place before the Association at this time in a more formal way. It is that a committee be appointed to consider and report upon the statistics of filter operation. It seems to me that there is need for some work to be done along this line, for when one studies and looks over the reports that describe the operation of filters in various parts of the country, he finds that they are in many ways very unsatisfactory. They are not uniform, and it is difficult to compare the results of one filter with those of another. There are many changes that need to be made in our methods of report. It seems to me that the whole subject is one that is worthy of being considered by this Association, and I therefore make the motion, Mr. President, that a committee of five be appointed to consider the subject of the statistics of filter operation and report at the next convention of the Association.

MR. FRANK W. GREEN.† *Mr. President,* — I would like to second that motion. In my position as superintendent of a filtration works, I have frequently noticed the need of such a report. It would be a very good thing if we could get some line on the subject, and have the reports from the many plants throughout the country conform, as nearly as is possible, to a given standard. As it is now, nearly every filter has its own form of report, some of them being rather too full and some are not explicit enough. The form of the reports would necessarily have to be changed from time to time. Only a few years ago very little attention was paid to the sterilization of water that had been

* See page 394.

† Superintendent of Filtration, Montclair Water Company, Little Falls, N. J.

filtered; the question of the pollution by bacteria was almost a sealed book at that time, while at present daily analyses of their number are made at many plants, and we can even detect whether the typhoid bacilli are present or not. The subject of free carbonic acid and the other properties that cause "red water," — they have assumed a very important position in some of our eastern supplies. We can, therefore, see how important it is to have a standard form of report, not only to enable us to secure data relative to the operation of the various plants as conducted in the past, but to enable us to more readily secure additional information along such lines as may develop in the future.

MR. GEORGE A. STACY. I want to know if that simply includes water filtration. I think it should go further and include sewage filtration, so that the comparison could be more easily made if it is desirable. It seems to me that sewage filtration is coming to the front very fast in this country, and the standardization of reports and statistics would enable them to be compared one with the other.

MR. ALLEN HAZEN. I think it is certainly as important in the case of sewage as it is with water. But this is a water-works organization, and it should be our endeavor to keep the sewage and the water as far apart as we can.

MR. STACY. I find that we would like to keep them as far apart as we can, but in spite of everything they are coming together and we have got to butt up against the whole question.

The motion was carried.

The President subsequently appointed the following committee: Prof. G. C. Whipple, Messrs. F. W. Green, E. E. Lockridge, F. D. West, and R. S. Weston.

EVENING SESSION.

The Secretary read the following list of applications for membership.

Active: John Hoffman Dunlap, Iowa City, Ia.; F. M. Griswold, New York City; Daniel A. McCrudden, Philadelphia, Pa.; D. C. Randall, Tupper Lake, N. Y.; Robert Robertson, Beverly, Mass.; Patrick Gear, Holyoke, Mass.; Francis D. West, Philadelphia, Pa.

Associate: S. E. T. Valve and Hydrant Company, New York City.

The applications were all properly endorsed and recommended by the Executive Committee, and on motion the Secretary cast a ballot in favor of the applicants.

Mr. Walter E. Spear, department engineer, Board of Water Supply, New York City, gave an illustrated paper on "The City Tunnel and Conduits of the Catskill Aqueduct." At the conclusion of his paper Mr. Spear called upon Mr. Lazarus White, in charge of the southerly half of the tunnel as division engineer, who gave some details in connection with the work. At the request of the President, Mr. Trautwine then showed some slides illustrating water hammer, and after a vote of thinks to the committee on arrangements for the excellent entertainment which they had furnished, the Convention adjourned.

EXECUTIVE COMMITTEE.

PHILADELPHIA, PA., September 10, 1913.

Meeting of the Executive Committee of the New England Water Works Association at Hotel Walton, at 10 A.M., Thursday, September 10, 1913.

Present, President J. Waldo Smith, and members William F. Sullivan, George A. Stacy, James L. Tighe, James W. Blackmer, Willard Kent, Lewis M. Bancroft, and George A. King.

Twenty applications for membership were received, viz.:

For members: D. C. Shull, superintendent Apollo Water Works Company, Apollo, Pa.; Walter P. Schwabe, general manager Northern Connecticut Light and Power Company, Windsor Locks, Conn.; N. W. Akimoff, hydraulic engineer, Philadelphia, Pa.; William J. Turnbull, engineer Mass. State Farm, State Farm, Mass.; Gen. Eugene B. Kontkovski, consulting engineer, General Corps of Engineers, St. Petersburg, Russia; M. B. Litch, superintendent and chemist Steelton Filtration Plant, Steelton, Pa.; Arthur N. Burnie, assistant superintendent Biddeford and Saco Water Company, Biddeford, Me.; E. W. Sylvester, superintendent public works, Poughkeepsie, N. Y.; Lazarus White, division engineer, Board of Water Supply of the City of New York; Weston E. Fuller, of firm of Hazen & Whipple, New York City; Frederick E. Tupper, commissioner public works, Quincy, Mass.; Jacob L. Langthorn, division engineer, Board of Water Supply of the City of New York; Wilbur Thomas Wilson, assistant engineer (designer) and assistant superintendent Board of Water Supply of the City of New York;

For associates: Joseph Dixon Crucible Company, Jersey City, N. J.; Simplex Valve and Meter Company, Philadelphia, Pa.; Electro Bleaching Gas Company, New York; James Boyd & Bro., Inc., Philadelphia, Pa.; American Bitumastic Enamels Company, New York City, N. Y.; Buffalo Meter Company, Buffalo, N. Y.; The Leadite Company, Philadelphia, Pa;

and the applicants were by unanimous vote recommended for admission in their respective grades.

Adjourned.

WILLARD KENT, *Secretary.*

PHILADELPHIA, PA., September 11, 1913.

Meeting of the Executive Committee of the New England Water Works Association at Hotel Walton, at 8.30 P.M., Thursday, September 11, 1913.

Present, J. Waldo Smith, President, and members William F. Sullivan, George A. Stacy, James L. Tighe, James W. Blackmer, Willard Kent, Lewis M. Bancroft, and George A. King.

Eight applications for membership were received, namely,

For members: F. M. Griswold, general inspector, Home Insurance Company, 56 Cedar Street, New York City, N. Y.; Robert Robertson, chairman Water Commissioners, 83 Lovett Street, Beverly, Mass.; Patrick Gear, superintendent Water Department, 42 Commercial Street, Holyoke, Mass.; Francis D. West, chemist in charge Torresdale Laboratory, Philadelphia Bureau of Water, Torresdale, Pa.; Dan A. McCrudden, 5931 Pulaski Avenue, Philadelphia, Pa.; D. C. Randall, superintendent Tupper Lake Water Company, Tupper Lake, N. Y.; John Hoffman Dunlap, professor hydraulics and sanitary engineering, State University of Iowa, Iowa City, Ia.;

For associate: S. E. T. Valve and Hydrant Company, New York City, N. Y.;

and they were by unanimous vote approved for membership in their respective grades.

Adjourned.

WILLARD KENT, *Secretary.*

MEMBERSHIP.

ADDITIONS.

(May 1 to December 1, 1913.)

MEMBERS.

N. W. Akimoff
Hydraulic Engineer, 1013 Harrison Building, Philadelphia, Pa.

Arthur N. Burnie
Assistant Superintendent Water Company, Biddeford, Me.

John H. Dunlap
Assistant Professor of Hydraulics and Sanitary Engineering, 311 Brown Street, Iowa City, Ia.

Joseph W. Ellms
Superintendent Cincinnati Filter Plant, 2807 Union Central Bldg., Cincinnati, Ohio.

Weston E. Fuller
Consulting Engineer, 30 East 42d Street, New York.

Patrick Gear
Superintendent Water Works, 42 Commercial Street, Holyoke, Mass.

F. M. Griswold
Fire Protection Engineer, General Inspector Home Insurance Company, 56 Cedar Street, New York, N. Y.

George H. Hazlehurst
Sanitary Engineer, Atlantic Coast Line Railroad Company, Wilmington, N. C.

Gen. Eugene B. Kontkovski
Consulting Engineer, General Corps of Engineers, 14 Erteleff Street, St. Petersburg, Russia.

Jacob S. Langthorn
Division Engineer, Board of Water Supply, New York City, 250 West 54th Street, New York, N. Y.

M. B. Litch
Superintendent and Chemist Steelton Filtration Plant, Steelton, Pa.

Edmund J. Lonergan
574 Salem Street, Malden, Mass.

Moses J. Look
General Superintendent, Winston & Co., Brown's Station, N. Y.

D. C. Randall
Treasurer and Superintendent Tupper Lake Water Company, Tupper Lake, N. Y.

Robert Robertson
Chairman Water Board, 83 Lovett Street, Beverly, Mass.

Joseph A. Rourke
Mechanical Engr., Public Works Dept., City of Boston, 743 Tremont St., Boston, Mass.

P. A. Shaw
Civil Engineer, 511 Hand Avenue, Lancaster, Pa.

Walter P. Schwabe
General Manager, Northern Connecticut Light and Power Company, 15 Central Street, Thompsonville, Conn.

D. C. Shull
Superintendent Apollo Water Works Company, Apollo, Pa.

Frank O. Sinclair
Civil Engineer, Burlington, Vt.

Edgar F. Smith
Assistant Designing Engineer, Board of Water Supply, Municipal Building, 22d Floor, New York, N. Y.

E. W. Sylvester
Superintendent Public Works, Poughkeepsie, N. Y.
Frederick E. Tupper
Commissioner of Public Works, Quincy, Mass.
William J. Turnbull
Chief Engineer, State Farm, Mass.
Arthur E. Walradt
Lawyer, 26 Liberty Street, New York, N. Y.
H. A. Von Schon
Consulting Hydraulic Engineer, 603 Wayne County Bank Building, Detroit, Mich.
Francis D. West
Chemist in charge Torresdale Laboratory, Bureau of Water, Philadelphia, Pa.
Lazarus White
Division Engineer, Board of Water Supply, 250 West 54th Street, New York, N. Y.
Wilbur T. Wilson
520 West 122d Street, New York, N. Y.
Fred J. Wise
Superintendent Water Works, Pittsfield, Mass.

ASSOCIATES.

American Bitumastic Enamels Company
109 Broad Street, New York, N. Y.
James Boyd & Bro., Inc.
25th and Wharton streets, Philadelphia, Pa.
Buffalo Meter Company
290 Terrace, Buffalo, N. Y.
Joseph Dixon Crucible Company
Jersey City, N. J.
Electro Bleaching Gas Company
25 Madison Avenue, New York, N. Y.
The Leadite Company
Land Title Building, Philadelphia, Pa.
S. E. T. Valve and Hydrant Company
50 Church Street, New York, N. Y.
Simplex Valve and Meter Company
208 Chancellor Street, Philadelphia, Pa.

CHANGES OF ADDRESS.

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T. Howard Barnes
321 St. Charles Street, New Orleans, La.
William T. Barnes
Of Metcalf & Eddy, 1824 Harris Trust Building, Chicago, Ill.
Edwin C. Brooks
353 Grove Street, Melrose, Mass.
D. McD. Campbell
Room 2, Davidson Building, Halifax, N. S.
Sidney K. Clapp
Board of Water Supply, Ashokan, Ulster County, N. Y.

W. Donaldson

The Birmingham Water Works Company, 2114 First Avenue, Birmingham, Ala.

Loring N. Farnum

Care General Petroleum Company, San Francisco, Cal.

Halsey French

Assistant Engineer, Board of Water Supply, Municipal Building, 22d Floor, New York, N. Y.

Richard H. Gould

Sanitary Engineer, Hillcrest, Poughkeepsie, N. Y.

Lyman P. Hapgood

Superintendent Water Works, Box 253, Jamestown, N. Y.

Robert J. Harding

Consulting Engineer, San Antonio Water Supply Company, San Antonio, Tex.

Herman K. Higgins

Care Chief Engineer, Culebra, Canal Zone.

Harry P. Letton

Sanitary Engineer, United States Public Health Service, 1315 Clifton Street, N. W., Washington, D. C.

Thaddeus Merriman

Assistant to Chief Engineer, Board of Water Supply, Municipal Building, 22d Floor, New York, N. Y.

James Newlands

With Henry Souther Engineering Corporation as Secretary and Consulting Sanitary Expert, 11 Laurel Street, Hartford, Conn.

Theodore Norcross

United States Department of Agriculture, Forest Service, Washington, D. C.

Raymond W. Parlin

Hydraulic and Sanitary Engineer, 46 Keystone Building, Kittanning, Pa.

Burton G. Philbrick

16 Ocean Avenue, Salem, Mass.

F. H. Robbins

Board of Water Supply, Municipal Building, 22d Floor, New York, N. Y.

Jas. F. Sanborn

700 W. 181st Street, New York, N. Y.

Charles W. Sherman

Of Metcalf & Eddy, 14 Beacon Street, Boston, Mass. Member Water Board, Belmont, Mass.

J. Waldo Smith

Chief Engineer, Board of Water Supply, Municipal Building, 22d Floor, New York, N. Y.

Sidney Smith

76 White Street, Boston, Mass.

George A. Soper

391 West End Avenue, New York, N. Y.

Ralph E. Tarbett

Sanitary Engineer, United States Public Health Service, Marine Hospital, 3d and Kilgour streets, Cincinnati, Ohio,

Lucian A. Taylor

Consulting Engineer and Contractor, 8 Dean Street, Worcester, Mass.

I. M. de Varona

Chief Engineer, Department Water Supply, Gas, and Electricity, 420 West 148th Street, New York, N. Y.

Thomas H. Wiggin

Municipal Building, 22d Floor, New York, N. Y.

Leonard P. Wood

Board of Water Supply, Municipal Building, 22d Floor, New York, N. Y.

ASSOCIATES.

Thomas D. Bausher
Church and Woodward streets, Reading, Pa.

DEATHS.

Arthur L. Adams,	September 17, 1913.
J. C. Hammond, Jr.,	Augest 24, 1913.
Horace G. Holden,	December 7, 1913.
Herbert P. Horton,	July 2, 1913.
George A. Nelson,	June 3, 1913.
A. N. Russell,	July 31, 1913.

New England Water Works Association

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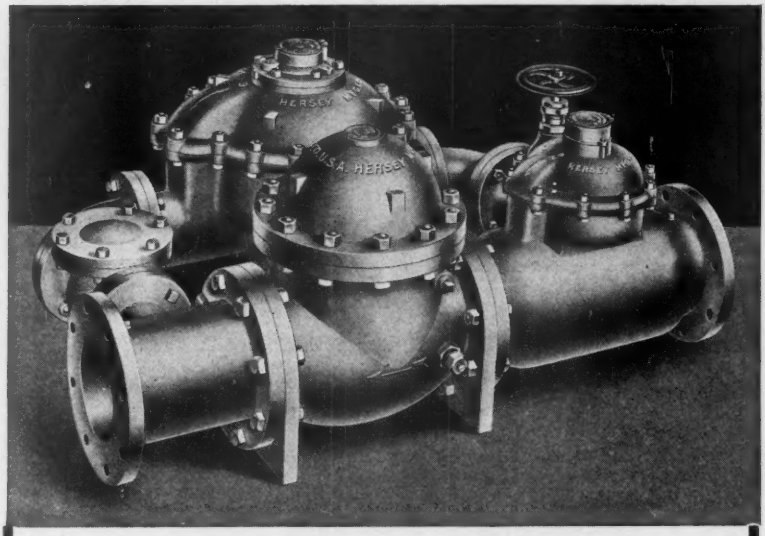

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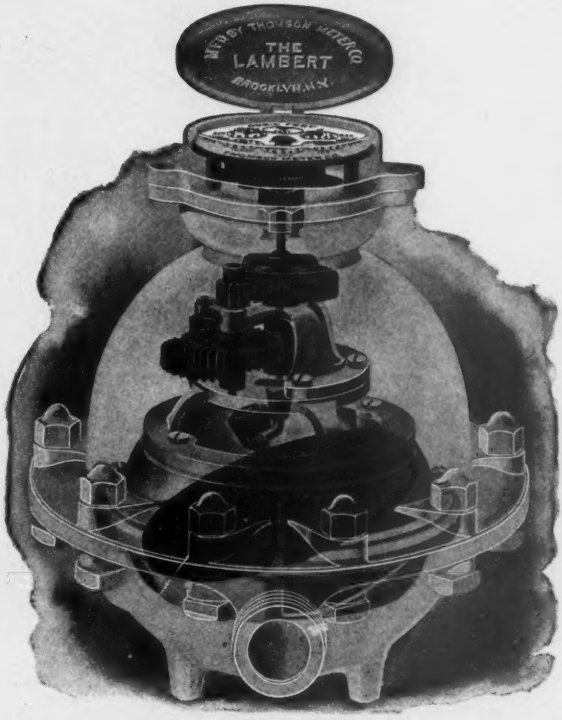

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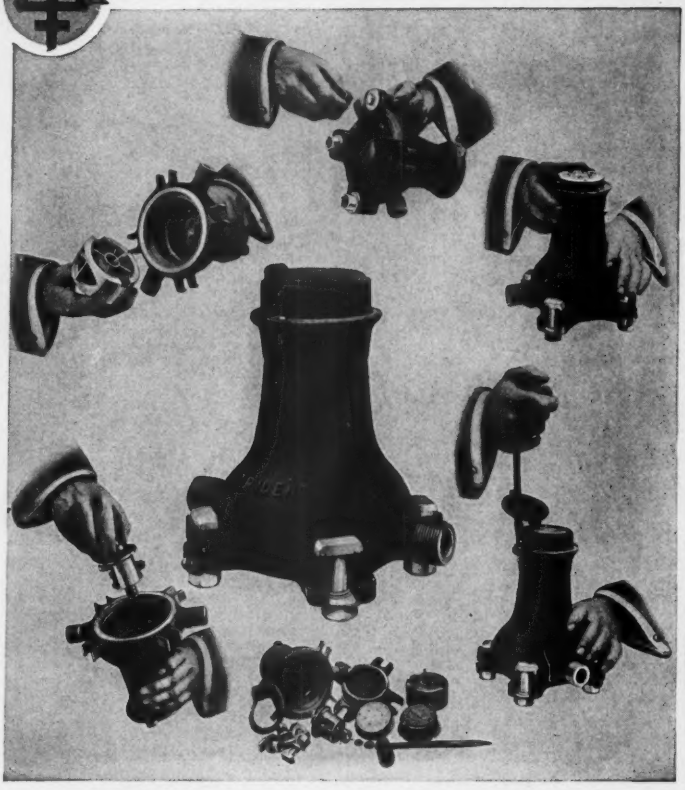

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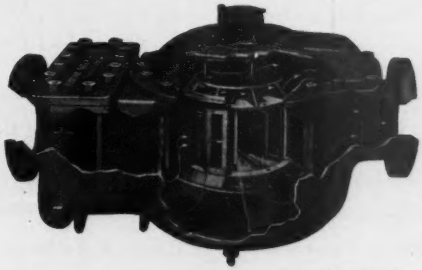

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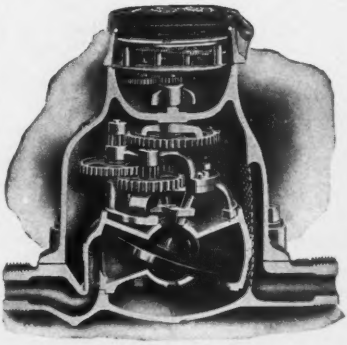

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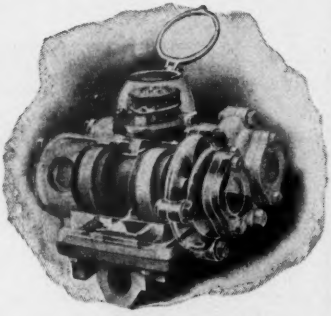

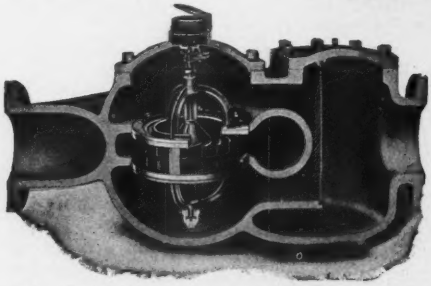

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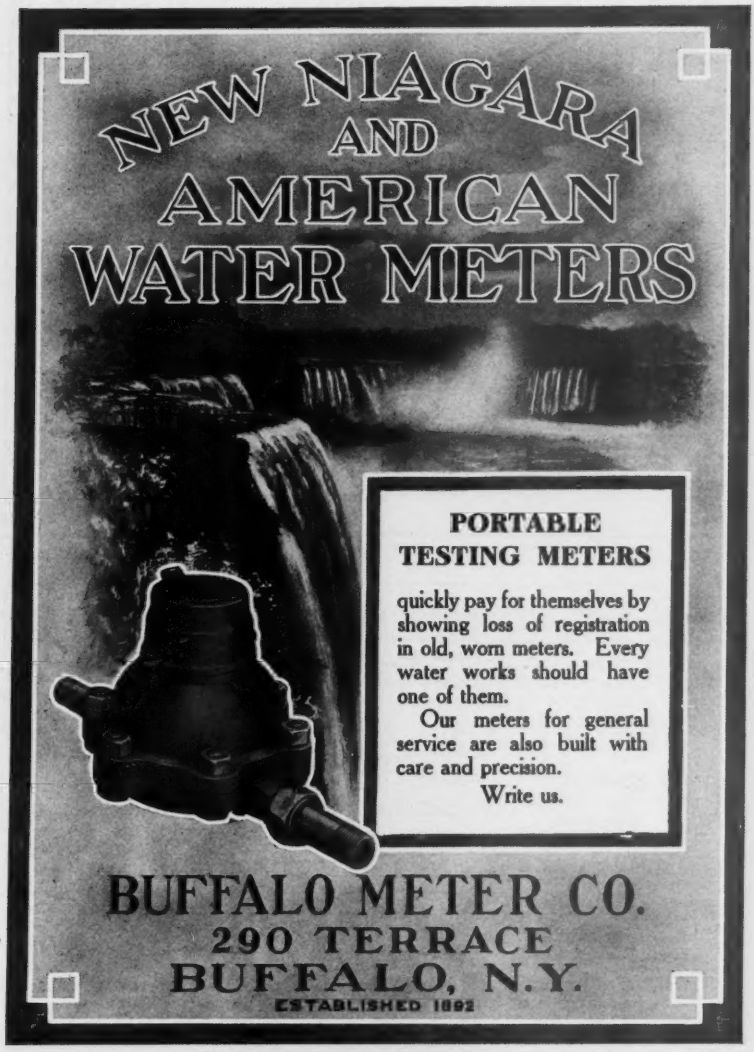
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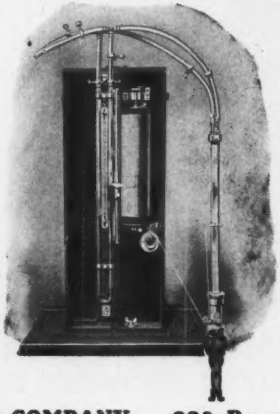

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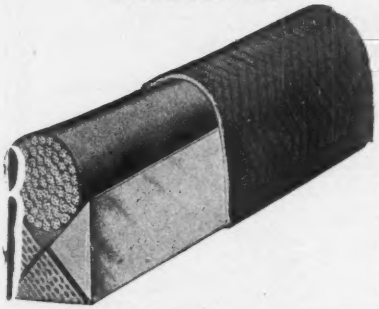

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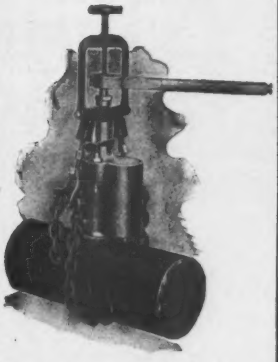

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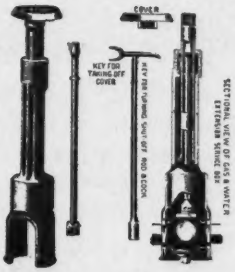

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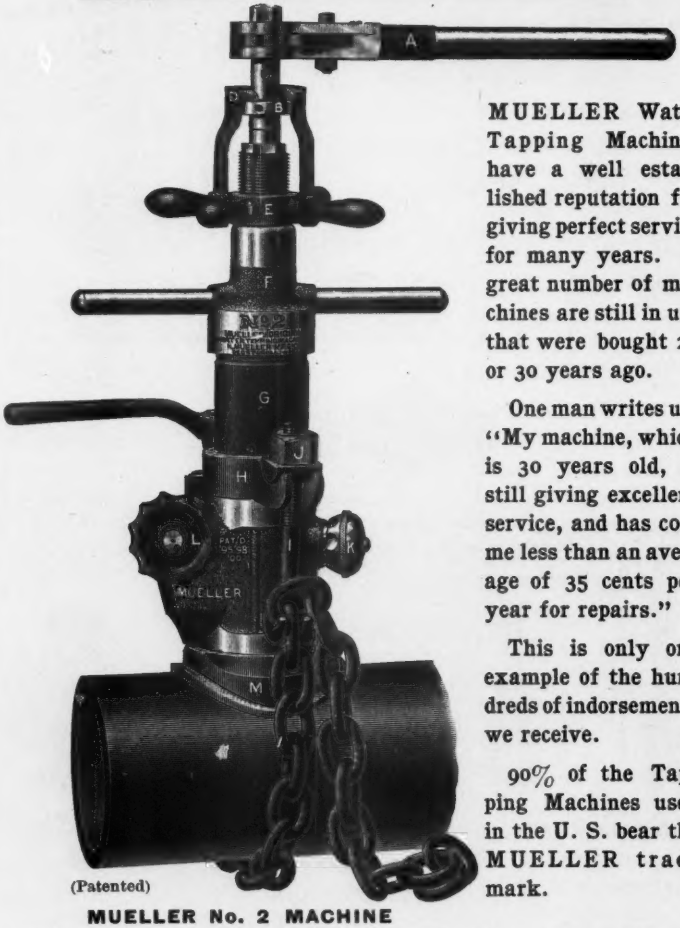

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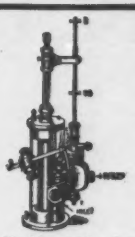

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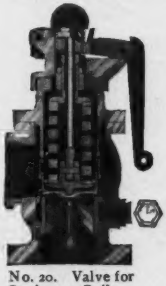

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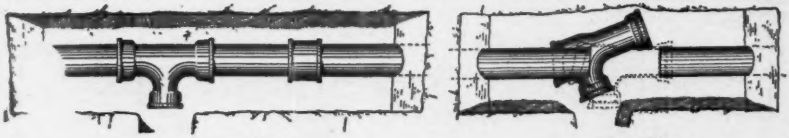

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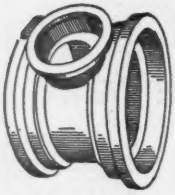

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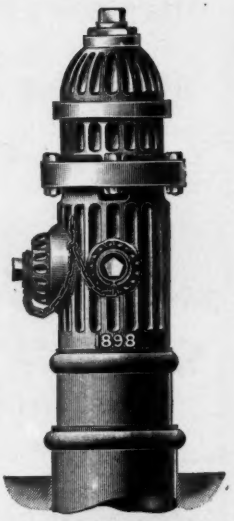

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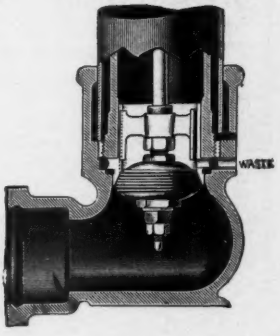

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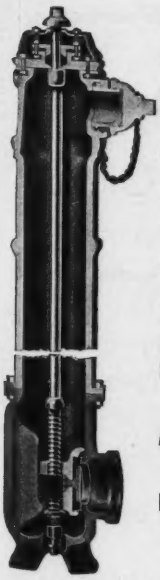

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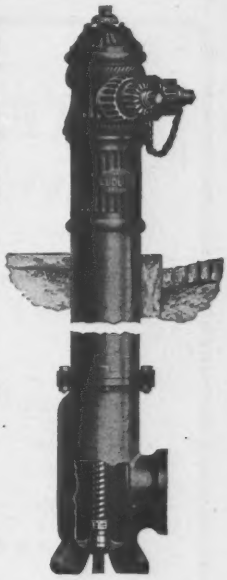

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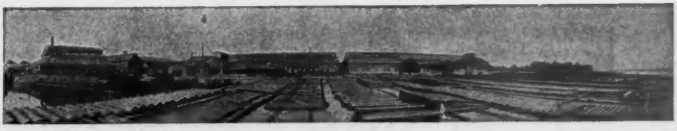

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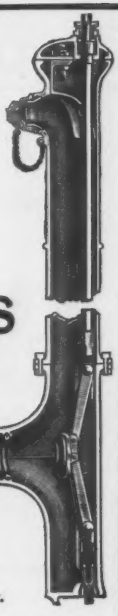

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For overhead joints, or in wet places where the use of molten lead is not only impracticable, but dangerous — **LEAD WOOL** may be employed to advantage. It makes perfectly tight joints to withstand the highest pressures, yet sufficiently elastic to admit of considerable sagging or settling of the pipe without causing the joint to leak. The difference in this respect, as compared with the poured joint, is notable.

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McLane Mfg. Co.

Write for a copy of "It Doesn't Affect the Water," which tells all about our proposition and the guarantee that we insist upon making.

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YOU SHOULD USE

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Registered U. S. Patent Office

FOR

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